ASSESSMENT OF LOG YARD RUNOFF IN ALBERTA

Results of Monitoring Program 1996 – 1998

103-06003/

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Prepared by

S. McDougall, P.Eng.
Southern Region, Approvals Group
Alberta Environment

June 2002

Pub. No: T/660
ISBN No. 0-7785-2267-9 (Printed Edition)
ISBN No. 0-7785-2269-5 (On-line Edition)
Web Site: http://www3.gov.ab.ca/env/info/infocentre/publist.cfm

Any comments, questions, or suggestions regarding the content of this document may be directed to:

Science and Standards Branch
Alberta Environment
4th Floor, Oxbridge Place
9820 – 106th Street
Edmonton, Alberta T5K 2J6
Fax: (780) 422-4192

Additional copies of this document may be obtained by contacting:

Information Centre
Alberta Environment
Main Floor, Great West Life Building
9920 – 108th Street
Edmonton, Alberta T5K 2M4
Phone: (780) 944-0313
Fax: (780) 427-4407
Email: env.infocent@gov.ab.ca

SUMMARY

As development of resources and urban areas increases and as point source releases improve in quality there is a greater focus on the quality of stormwater and its impact on the environment. A monitoring program was designed and implemented in 1996 and ended in the fall of 1998 as part of a recommendation of a study of log yard runoff conducted in 1995 by Alberta Environment. The monitoring program consisted of monitoring at five log yard test sites and three forested area control sites. A total of 11 samples were collected at the control sites and 97 samples from the log yard sites. This report summarizes and provides an assessment of these monitoring results including:

- characterization of the storm water runoff quality from Alberta log yards and forested areas in terms of chemical constituents and the toxicity as measured by bioassay tests. Chemical testing included pH, TSS, organics such as BOD, COD, TOC, phenols, resin and fatty acids, and nutrients. Bioassay testing included determining acute lethality of effluents to Rainbow trout and *Daphnia Magna* and toxicity testing using luminescent bacteria (Photobacterium phosphoreum),
- comparison of the log yard runoff quality with runoff from forested areas, typical storm water and bioassay test limits and an assessment of the potential factors contributing to the quality of the runoff, and
- Best Management Practices (BMPs) for log yards based on the results of the monitoring program and a review of policy and guidelines in other jurisdictions.

Findings

- Log yard runoff had higher concentrations of organics, such as COD, BOD, TOC, and phenols, compared to runoff from forested areas.
- Bioassay test results showed that log yard runoff can range from completely non-toxic to toxic with LC50's of relatively low concentrations. The bioassay test results of the forested area control samples were less variable and had lower toxicity.
- The log yard runoff quality, regardless of the site characteristics, exceeded typical stormwater limits for COD and TSS but was within the accepted stormwater limit range for pH of 6.0 to 9.5.
- Log yards with clay soils, defined runoff paths and pine or aspen logs at the site had higher organic levels in their runoff compared to a site with spruce logs and a muskeg/clay surface.

Approaches to Managing Log Yard Runoff

The findings of the monitoring program support the general approach, to manage runoff from log yards by implementing Best Management Practices (BMPs), taken in the United States, Washington State, Ontario, New Brunswick and B.C, and outlined in Alberta Environment's report *Assessment of Log Yard Runoff in Alberta* June 1996. Examples of these BMPs are provided in a document published by The State of Washington Department of Ecology (1995) and include:

- Divert storm water around storage areas with ditches, swales and /or berms.
- Stack materials to minimize surface areas of materials exposed to precipitation.
- Direct stormwater to a retention pond,
- Install aeration in the pond if the organic levels (BOD, COD, TOC) remain high.
- Install innovative treatment methods such as biofiltration (grassy swales, vegetative filter strips) or constructed wetlands for BOD, COD, and TOC.

ACKNOWLEDGEMENTS

I would like to acknowledge the companies that participated in the log yard runoff monitoring program, Neil Shelly of the Alberta Forest Products Association, and the following individuals from Alberta Environment who assisted in the program and report preparation including Jay Nagendran; George Scammell, Kim Morrison, Tom Trimble, Alan Undershultz, Martin Bundred, Anne-Marie Anderson, Elaine Wasylenchuk, Suzanne Lazorko- Connon, Bijan Aidun, Randy Angle and Dr. Stephen Stanley of the University of Alberta, supervisor of my Masters of Environmental Engineering project, and the numerous people who contributed to this study and report with their comments and suggestions.

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GLOSSARY

Acute — Refers to short-term exposures lasting 96 hours or less. It always measures lethality. Rainbow Trout Acute Bioassay test measures the mortality of 10 juvenile rainbow trout exposed to a test solution such as a wastewater source for 96 hours. Daphnia Magna Acute Bioassay measures mortality of daphnia magna exposed to a test solution for 48 hours. (Environment Canada, 1990).

Ammonia — Ammonia is a potentially toxic by-product of anaerobic decomposition of wood waste (Samis *et. al.*, 1991). Its presence is known to be toxic to fish at certain levels.

BOD — Biochemical Oxygen Demand, the oxygen required by microbes for the biochemical degradation of organic matter under aerobic conditions. BOD is therefore an indirect measure of organic matter. BOD_5 signifies that the test was conducted over a 5-day period.

Chronic — Refers to long-term exposure lasting at least 1/10 of the life span of the organism.

COD — Chemical Oxygen Demand is a gross measure of the oxygen required for the complete oxidation of a substance to carbon dioxide, water and ammonia. The COD test is capable of measuring complex organic molecules such as tannins and lignin, which are not readily available as nutrients to bacteria. (Slagle, 1976).

Daphnia magna — Is a waterflea and "as a small freshwater crustacean of the Order Cladocera. It is found in pools and lakes of North America including western Canada and is an important component of aquatic communities. Daphnids are sensitive to a broad range of aquatic contaminants, and are used in toxicity tests internationally. They have the advantage of small size, short life cycles (which allow rapid tests), and relative ease of culture in laboratories." (Environment Canada, 1990).

EC50 — Is the median effective concentration in a test solution such as water or wastewater to cause a specified non-lethal or lethal effect in 50% test organisms. (Environment Canada, 1990).

LC50 — (median lethal concentration) Concentration of test solution that is lethal to 50 percent of the test organisms. (Environment Canada, 1990).

Lignins — "Lignins are compounds which are predominantly amorphous polymeric aromatics and are responsible for much of the strength of the cell walls in plant tissues. Lignin is generally not soluble in most liquids." (Moore, 1992)

Microtoxicity — Exposes a marine bacterium that emits light as a metabolic by product to a test solution. The bacterium produces less light when the test solution is stressful or lethal to it. The test requires very little test solution, about 2.5 ml for each test, but two or three runs are usually conducted because of the inherent variability of the test. Test concentrations are normally 5.6, 11.3, 22.5 and 45 percent of the water or effluent. This is a rapid test (15 minutes) and is useful as a screening tool for toxicity.

Oil and Grease Oil and grease concentrations would more likely be indicative of operational processes rather than leaching from logs. High levels of oil and grease would indicate log yards require better housekeeping practices on site.

pH Low pH has been found to be a characteristic of wood waste leachate and has been observed in leachate from aspen wood. " The low pH is due, in part, to the organic acid extractives in the leachate" (Moore, 1992). The organic acid extractives include resin and fatty acids, and phenolic compounds such as phenols, lignins and tannins. It has also been suggested that carbon dioxide produced by the decomposition of wood contributes to the acidity of the leachate as carbonic acid (Samis *et. al.*, 1991).

Phenols Phenol is an aromatic alcohol with a chemical formula of $C_6H_{11}OH$. An aromatic structure has carbon atoms connected in a planar ring structure. Alcohols are hydrocarbons in which one or more of the hydrogens have been replaced by a hydroxo group, OH^-. High levels of phenols have been identified in aspen wood leachate (Taylor, 1994).

Phosphorous Phosphorous is considered a nutrient because it is essential to the growth of biological organisms including algae. There is interest in controlling the amount of phosphorous release to receiving water bodies because of concerns regarding the growth of algae and weeds in water bodies and their consumption of dissolved oxygen with possible environmental impacts.

Resin Acids Resin acids have been found to be acutely toxic to fish. The toxicity of resin acids have been found to be additive for this group of structurally similar compounds which are believed to exert their toxicity in a similar manner. Resin acids have been found to be stable against abiotic break down and apparently require bacterial or fungal enzyme systems to degrade them. However, they can bioaccumulate, but except for dehydroabietic acid, they have not been found to be very persistent (Taylor *et. al.*, 1988). Samis *et. al.* (1991) classify the high concentrations of resin acids in Douglas fir and spruce as the primary toxicants in leachate from these species. resin acids found in the resin canals in the bark and sapwood.

Seasons Spring (March 20 – June 19), Summer (June 20 – September 21), Fall (September 22 – December 20), Winter (December 21 – March 19)

Rainbow Trout Bioassay "Rainbow trout *Orcorhynchus mykiss*, native to western North America but now inhabiting waters of all Canadian provinces and widely introduced around the world. It thrives in cool, fresh water, runs to sea on both Atlantic and Pacific coasts, and is commonly reared in hatcheries and commercial aquaculture. It has also become the world's standard cool-water fish for freshwater toxicity tests, with a toxicological data bank of appreciable magnitude." (Environment Canada, 1990)

Tannins Tannins are a group of highly soluble aqueous extractives, comprised of substances with a high proportion of free phenolic hydroxyl groups and varying degrees of polymerization (Moore, 1992). The toxicity of western hemlock bark has been attributed to its tannin content (Samis *et. al.*, 1991).

TOC	TOC (Total Organic Carbon) is a measure of the organic carbon which is oxidizable by COD or BOD tests, plus other organic carbon which does not respond to oxidation by COD or BOD. The TOC test does not measure other organically bound elements such as nitrogen.
Toxicity	"Toxicity means the inherent potential capacity of a material to cause adverse effects in living organisms." (Environment Canada, 1990).
Toxicity Testing	A procedure to determine the toxicity of a chemical or an effluent on a living organism. Its purpose is to estimate the degree of toxicity and express it in terms of a threshold concentration or time required to cause an effect.
TSS	Total Suspended Solids. Runoff from log yard areas may contain high TSS, which may increase turbidity and influence colour or ionic composition of the receiving water body.

1.0 INTRODUCTION

Stormwater from industrial, agricultural and urban areas has been recognized within the last twenty years as a potential environmental concern due to its impacts on the water quality of receiving water bodies. In Alberta, industrial stormwater management is assessed on a site-specific basis and limits have been established for certain industrial sectors. Prior to the early 1990's stormwater runoff from log yards was not considered a high risk for adversely effecting the environment.

In the early 1990's, laboratory and field studies conducted for the B.C. Ministry of Environment investigated the quality of the leachate generated from logs. These studies, which included the use of trout as indicator organisms, indicated the leachate could impact receiving streams due to the high organic load and leachate chemistry. Alberta Environment (AENV) also noted public concern regarding log yard runoff leaving a wood processing plant. To address these issues, AENV conducted a study in September 1995. The study included an inventory of the surface water runoff control measures at 33 Alberta log yards, a literature review on the chemical characteristics of log yard runoff and a policy review for the control of surface water runoff from log yards in other jurisdictions. The results of this study were documented in *Assessment of Log Yard Runoff in Alberta – Preliminary Evaluation*, June 1996. Details of the study are provided below.

The inventory of surface runoff control measures at the 33 Alberta log yards revealed that twelve log yards had passive treatment such as infiltration or vegetated buffer strips, twelve redirected the runoff from the log yard by ditching, seven had retention ponds or dug outs and two treated runoff with their industrial wastewater by biological wastewater treatment.

The literature review of surface runoff from log yards indicated that the runoff can be highly variable, both in chemical characteristics and toxicity. The literature review identified that the variable quality included elevated levels of 5-day Biochemical Oxygen Demand (BOD_5) and Chemical Oxygen Demand (COD), phenolic compounds and substituted benzenes and Total Suspended Solids (TSS). BOD and COD measure the oxygen demand or organic load of a substance. Phenolic compounds and substituted benzenes, including resin and fatty acids and tannins, are known to be toxic to aquatic life at certain levels.

The policy review found that other jurisdictions such as the United States Environmental Protection Agency and Ontario Ministry of Environment and Energy require the development and implementation of a Best Management Practices Plan as a means of reducing contaminant loading to the maximum extent possible.

Recommendations from the report *Assessment of Log Yard Runoff in Alberta* included:

- establish good housekeeping practices at all log yards;
- implement a monitoring program to characterize log yard runoff at Alberta log yards;
- use the results of the monitoring program to determine the necessity of additional runoff control measures at existing sites and provide information to refine Best Management Practices for log yards;

- require the development of Surface Runoff Management Plans (SRMP) at Alberta log yards. Suggestions for developing a SRMP are provided in Appendix A, and
- require new facilities to implement runoff control measures.

This report presents the results of the monitoring program AENV undertook with the Alberta Forest Products Association (AFPA) and wood processing plants from 1996 to 1998. The report is divided into seven sections, including this section. Section Two outlines the log yard runoff monitoring program design for the two year monitoring program and its implementation and limitations. Section Three describes the test and control sites. Section Four provides an overview of wood chemistry and results of a literature review of log yard runoff, Section Five describes the monitoring results, Section Six provides the data analysis, Sections Seven provides conclusions and Section Eight provides Approaches for Managing Log Yard Runoff.

2.0 LOG YARD RUNOFF MONITORING PROGRAM DESIGN & IMPLEMENTATION

The design of the log yard runoff monitoring program consisted of determining the objectives of the program and deciding on an approach to meet the objectives. The two sections below outline these steps.

2.1 Monitoring Program Objectives

The results of the literature review conducted as part of the preliminary evaluation of log yard runoff in 1995 – 1996 indicated that log yard runoff quality could have a wide range of chemical characteristics which included varying toxicity. These chemical characteristics included BOD levels ranging from 6 mg/L to 4,950 mg/L, COD levels ranging from 11 mg/L to 6,530 mg/L and TOC levels ranging from 20 to 2,230 mg/L. To further understand the quality and quantity of stormwater runoff from log yards in Alberta, a monitoring program was designed by AENV and presented to the Alberta Forest Products Association (AFPA) in March 1996 for discussion. By understanding better the quality and quantity of log yard runoff, an approach to addressing potential impacts due to stormwater runoff from log yards could be formulated and implemented. This approach reflects the current proactive pollution prevention approach being applied to stormwater releases.

The monitoring program objectives were the following:

1. Measure the load of contaminants, including organics, nutrients and toxicity being generated by log yards. Compare this contaminant load with:
   - Control or background runoff quality and quantity from natural processes in comparable forested areas.
   - Typical storm water limits and limits for bioassay tests.
2. Determine which parameters are contributing to the potential impact if log yard runoff is higher than control or background runoff and limits discussed above.
3. Determine the factors which are contributing to the generation of these contaminants, if possible.

2.2 Monitoring Program Approach

The approach taken to meet the monitoring program objectives was to ensure that sufficient sites would be monitored and that events were monitored frequently and thoroughly enough to capture a representative loading from the site. The data collected would then be used to meet the objectives listed above. The general approach for this program was to:

1. Select three log yard sites and nearby control sites;
2. Set up the monitoring program and protocol to follow;
3. Collect samples and measure the flow of runoff from log yards and control sites;
4. Conduct chemical and toxicological characterization of the runoff;
5. Compare the log yard and control runoff quality;
6. Compare the runoff quality to typical storm water limits and water quality guidelines;

6. Determine the most important factors influencing log yard runoff e.g. log species, size of the log yard, soil / topography, management of the log yard, precipitation at the site, and
7. Use this information to develop practises to mitigate any potential impacts of log yard runoff.

The proposed time period for monitoring was over a two-year period. The proposed frequency was once during spring runoff and twice during summer storm events. The highest runoff flows from the site are expected to occur during the spring runoff and summer storms. As a result the runoff has an increased capacity to carry suspended solids and other contaminants from the log yard depending on the intensity and duration of the event. Spring runoff is also when the majority of companies have their maximum inventory of logs after winter hauling.

It was proposed that the monitoring program would be undertaken at three log yard sites and control sites. Later, two additional log yards were included in the monitoring program for a total of five log yard sites. Factors taken into account in determining which sites to include in the monitoring program included:

- Proximity to receiving water bodies and the runoff control measures in place;
- Industry's participation and assistance available;
- The size of the log yard, the log species stored, the amount of logs stored, the management practices such as the way the logs are stored, frequency of debris clean up, and
- Differences in soil and topography of the various log yards.

The ideal site was considered to have the following characteristics:

- A well defined drainage path to enable samples to be taken easily and to quantify flow;
- Soils and landscape combinations which promoted surface runoff, i.e., fine grained soils and sloped terrain favour surface runoff compared to sandy soils and flat terrain;
- Sites closer to Edmonton, or sites where AENV staff could check on their status, and
- An "undisturbed" drainage basin close by to act as a "control site".

The forested areas chosen as control sites were to be undisturbed (undeveloped) forested areas close enough to the log yard site to travel quickly to, to obtain samples and have a well defined drainage path to enable samples to be taken easily and to quantify flow.

The water quality sampling consisted of field measurements and chemical analysis conducted in the laboratory. Field measurements included pH, temperature, dissolved oxygen and specific conductivity. Laboratory analyses included pH, temperature, dissolved oxygen, specific conductivity, BOD, COD, TOC, TSS, total phenols, tannins and lignins, resin and fatty acids, ammonia and toxicity testing consisting of Trout bioassays to determine LC50 @ 96 hrs, Daphnia magna bioassays to determine LC50 @ 48 hrs, EC50 @ 48 hrs and microtoxicity testing. Not all samples had all these listed parameters analyzed. The glossary provides a brief description of the analyses conducted and the significance of these parameters.

Runoff from log yard sites was to be estimated based on hydrological data and direct measurements. It was proposed that measurements would be done three times per day during flow or runoff conditions (i.e. at least as frequently as water quality sampling). To estimate the total volume of discharge, each of the flow rates would be multiplied by a time interval that represents the portion of the total storm duration associated with the measurement, and then all

the partial volumes would be added. As a result of difficulties described in Section 2.4, quantities of runoff leaving test and control sites were not estimated.

2.3 Implementing the Monitoring Program

As indicated in Section 2.2, sampling was to be conducted over a two-year period to include a total of two spring runoff events and four summer rainfall events. Table 1 summarizes the sampling that was conducted at each of the test sites, the dates and the number of samples collected.

During the 1997 sampling period the AFPA hired a single consultant (Maxxam Analytic/Chemex Labs) to train company personnel in the proper collection and handling procedures. The sampling equipment was also supplied for each site by the consultant. The arrangement was that the participating site would contact AENV personnel at the beginning of the runoff event and AENV staff would travel to the site and collect the samples.

Table 1 Summary of Sampling Conducted

(Test sites described in Section 3, Time period of sample with number of samples in brackets)

Test Site	Wood Species	Sampling Conducted By	Date	No. of Samples
#1	Aspen	AENV[1]	Spring 96 (1), Summer 96 (2), Spring 97 (2)	5
		AGAT[2]	Spring 96 (2), Summer 96 (8)	10
		AGAT	Fall 96 (9), Spring 9? (1)	10
		AFPA[3]	Spring 97 (4), Summer 97 (4)	8
	Control	AENV	Summer 96 (1), Spring 97 (1)	2
		AFPA	Summer 96 (1), Fall 96 (1)	2
#2	Pine	AENV	Spring 96 (1), Spring 97 (1), Spring 98 (1)	3
		Sunpine[4]	Winter 96 (3), Spring 96 (2), Spring 98 (2)	7
	Control	AENV	Spring 96 (1), Spring 98 (1)	2
		Sunpine	Spring 96 (2), Spring 98 (1)	3
#3	Conifer	AENV	Spring 96 (2), Spring 97 (2)	4
		AFPA	Spring 96 (1), Fall 96 (3), Spring 97 (4), Summer 97 (4)	12
	Aspen Conifer	AENV	Spring 96 (1), Fall 96 (1), Spring 97 (1)	3
		AFPA	Spring 96 (1), Fall 96 (3), Spring 97 (4), Summer 97 (4)	12
	Control	AENV	Spring 96 (1), Spring 97 (1)	2
		AFPA	Spring 96 (1)	1
#4	Spruce	AENV	Spring 97 (4)	4
		AFPA	Spring 97 (4), Summer 97 (4), Fall 97 (1)	9
#5	Conifer	AENV	Spring 97 (1)	1
	Conifer	AFPA	Spring 97 (4)	4
	Aspen	AENV	Spring 97 (1)	1
	Aspen	AFPA	Spring 97 (4)	4

AENV[1] refers to Alberta Environment, AGAT[2] refers to AGAT & Associates, AFPA[3] refers to Alberta Forest Products Association, Sunpine[4] refers to Sunpine Forest Products Ltd

2.4 Limitations of the Monitoring Program

Although the monitoring program was intended to cover diverse sites and environmental conditions, the design was largely governed by the willingness of facilities to participate in the monitoring program, the wood species that the facility processed, and site conditions. For example, sites chosen were limited to those where the conditions included a defined runoff path and a location to collect a sample. There are many things that could not be controlled, for example, the amount of precipitation that fell, the type of wood species processed at test sites, the size of the log yard, the length of time that a log was stored at the site, etc. This demonstrates that a factorial type design study was impossible.

A wide range of factors that influenced quality and quantity of runoff during sampling also complicated the monitoring program as well as the data interpretation. Weather conditions, such as the amount of precipitation affected the quantity of runoff generated. The inability to record all the site conditions at the time of the sampling event limited the factors that could reasonably be considered in interpreting the data. Thus only major factors, such as log yard area, wood species and log yard management practices, that had been recorded at the initial site visit in 1995 and 1996, were used in evaluating potential and observed environmental effects.

The major difficulty in implementing the monitoring program was found to be the logistics of getting equipment and people to the sites during spring runoff and summer storm events. The logistics of people being available on very short notice in addition to travelling to the site to capture the event posed problems. This continued to be a difficulty for AENV as the log yard runoff monitoring program was one sampling program out of many that the sampling staff participated in. The majority of the monitoring was conducted by plant personnel or the consultant hired by the AFPA to do so. Due to field difficulties and time constraints not enough measurements were taken of the runoff flow from the test and control sites. As a result, quantities of the runoff leaving test and control sites were not estimated.

The AFPA was involved with finalizing the monitoring program. AFPA members provided funding for monitoring all five log yard sites. AENV funded sampling and analysis that was conducted by their staff. The tables in Appendix C indicate the organization that collected the sample and funded the analysis. The next section describes the log yard and control sites that were selected.

3.0 SITE SELECTION

Three log yard and nearby control sites were established for the 1996 – 1997 monitoring period. Two additional log yard sites were added to the monitoring program in 1997 – 1998. Figure 1 is a map showing the locations of the test and control sites. Site plans for each of the test sites are provided in Appendix B. Information on the characteristics of the log yard monitoring sites is summarized in Table 2. Table 3 describes the general location, watershed and surface runoff control measures and Table 4 presents the log handling and maintenance practices. Descriptions of each site including the general location and the log yard and runoff management follow these tables.

Table 2 Characteristics of the Log Yard Monitoring Sites

Test Site	Company	Location	Log Yard Area hectares (acres)	Soil Type	Maximum Inventory (m^3)	Log Species
#1	Weyerhaeuser Canada Limited – Oriented Strand Board (OSB) Plant	Edson	12.1 (30)	silty-clay	170,000	Aspen (70%), black poplar (25%) birch (5%)
#2	Sunpine Forest Products Ltd. - Laminated Veneer Lumber (LVL) Plant	Strachan	13.6 (34)	silty- clay till with gravel 0.6 – 2 m beneath the surface	120,000	80% pine and 20% spruce
#3	Weyerhaeuser Canada Limited - OSB & Sawmill Plant	Drayton Valley	24.3 (60)	clay surface to 4m depth sandy – silty clay 10m below that	270,000 (conifers) 190,000 (aspen)	Aspen (40%), black poplar (10%), lodgepole pine (20%), white spruce (30%).
#4	Zeidler Forest Industries Ltd.– OSB Plant	Slave Lake	32.4 (80)	muskeg and clay built up with pit run and gravel	393,000	spruce, (88%), pine (7%) and balsam fir (5%)
#5	Millar Western Industries Ltd.- Pulp Mill & Sawmill	Whitecourt	16.2 (40)	Gravel	750,000	61% softwood (34% pine, 26% spruce, 1% fir) 39% hardwood (35% aspen, 4% black poplar)

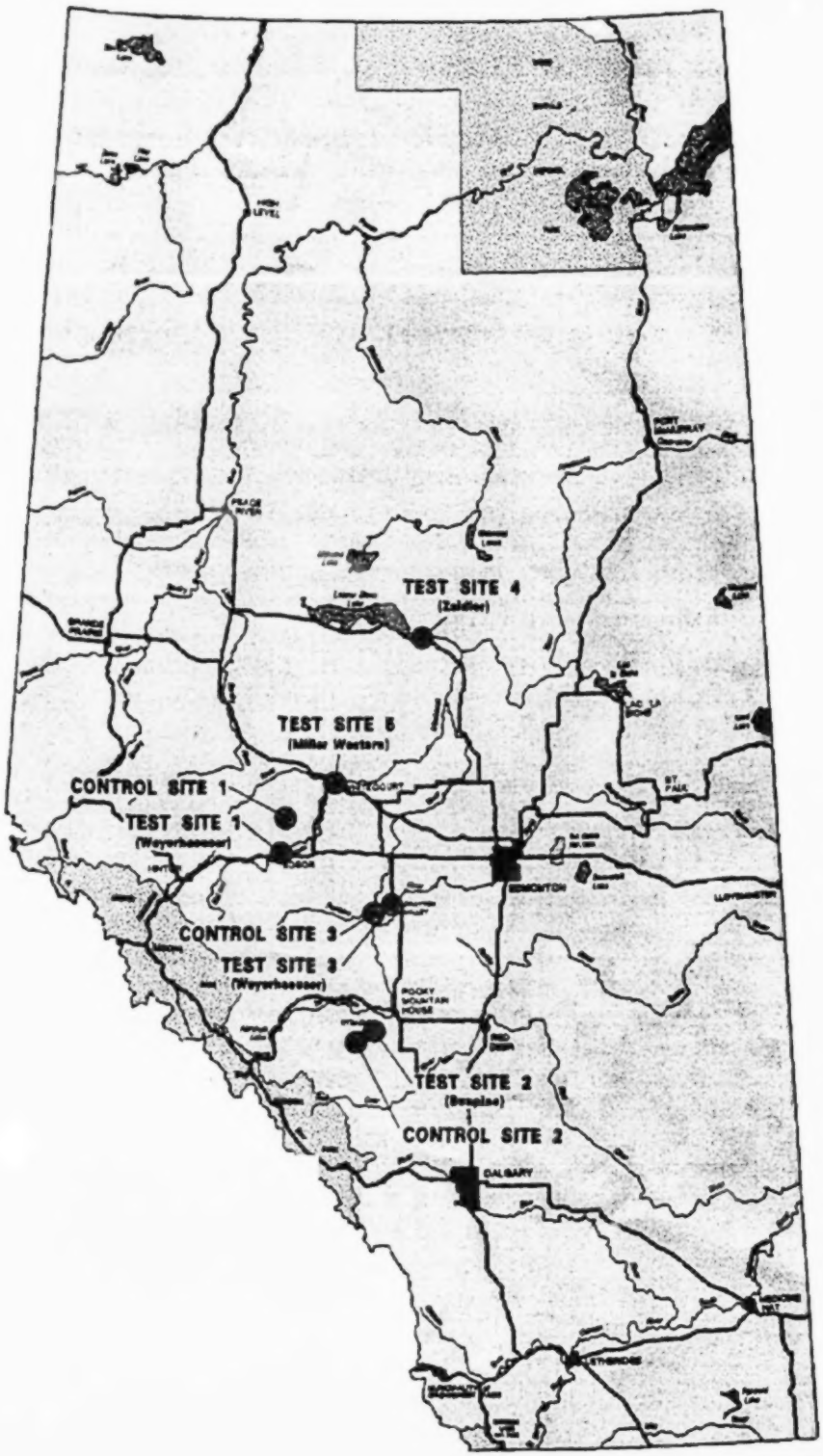


Figure 1 **Test and Control Sites for Log Yard Runoff Monitoring Program**

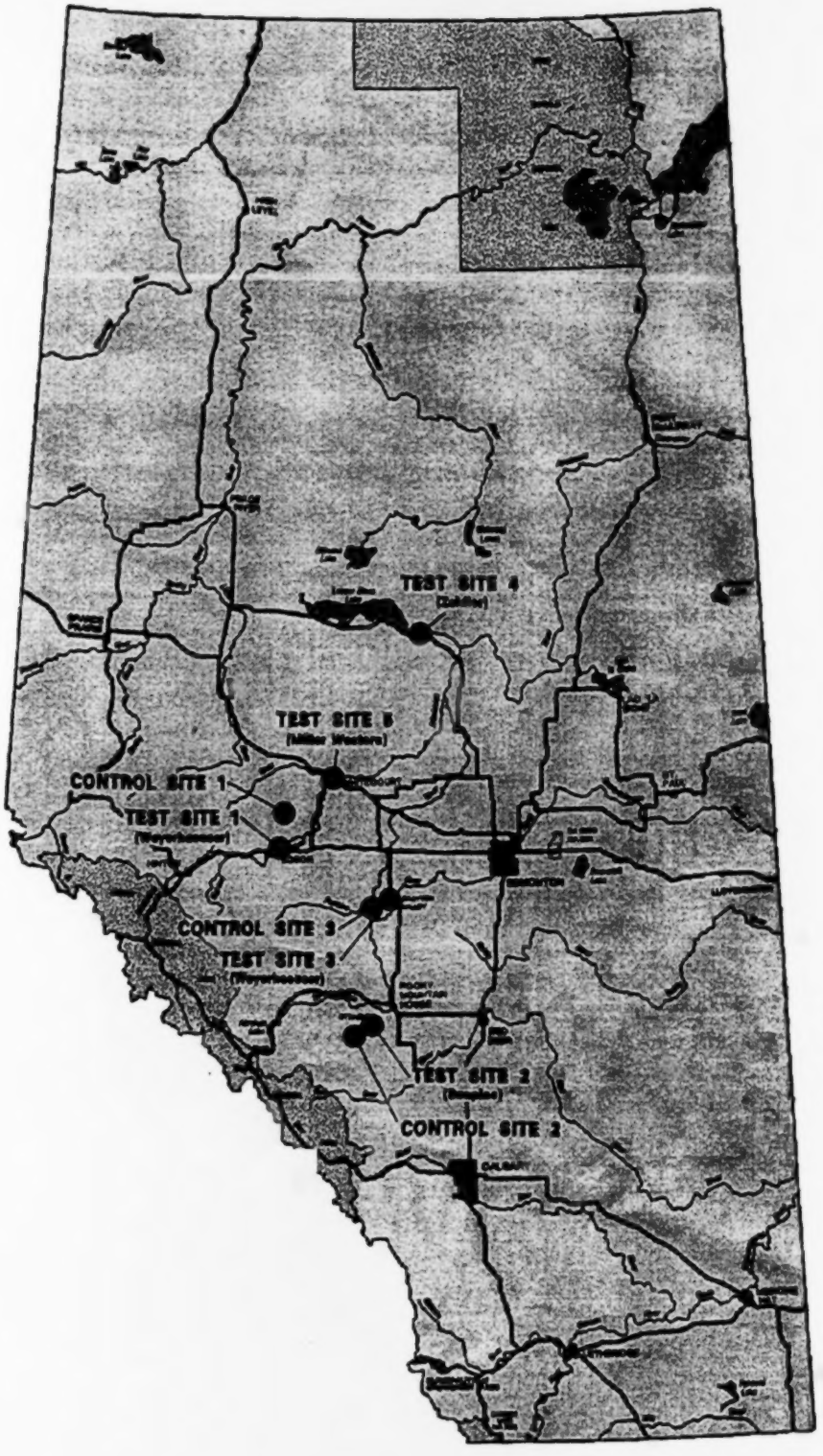


Figure 1 **Test and Control Sites for Log Yard Runoff Monitoring Program**

Table 3 Surface Runoff Control Measures

Test Site	Location	River Basin (Id #)	Proximity of Facility to Water Body	Runoff Control Practices	Additional Information
#1	NE 23-53-17-W5M 1 km north of Highway 16 near Edson	Athabasca (7AG)	1.5 km north of MacLeod River	pond	Runoff is recycled to the log conditioning ponds
#2	S.W. ¼ 2 & S.E. ¼ 3-38-9-W5M 30 km southwest from Rocky Mountain House	North Sask. (5DB)	2.5 km south of Prairie Creek	ditch	Runoff directed via ditches then into forest, prior to the study the log yard was graded, gravelled and erosion control mechanisms installed.
#3	S.W. ¼ 8 & N.W. ¼ 5-49-7-W5M, south from Drayton Valley	North Sask. (5DE)	11 km northwest of North Saskatchewan River. Borders West Park Creek	ditch	Runoff is directed to West Park Creek then to a beaver pond. (The town of Drayton Valley discharges storm sewer to the creek)
#4	NW ¼ 30-72-4-W5M. Mitsue Industrial Park M.D. of Lesser Slave Lake	Athabasca (7BK)	2 km south of Lesser Slave River, 1 km north of Mitsue Lake	ditch passive	Runoff flows N of site either via ditches through 3 km of bush to Lesser Slave R. or to the surrounding muskeg
#5	NW ¼ 35-59-12-W5M. northwest of Whitecourt	Athabasca (7AH)	100 m south of Athabasca River, 100 m east of MacLeod River	passive	Runoff flows to the surrounding environment and likely infiltrates.

Table 4 Log Handling and Maintenance Practices

Test Site	Log Handling Practices	Log Yard Maintenance Practices
#1	Tree length logs mobile equipment	Site is scraped and graded each year after logs are recovered.
#2	Cut to length logs and tree length logs, mobile equipment	Site is scraped and graded each year after logs are recovered.
#3	Tree length logs, mobile equipment	Site is cleaned each year; any wood debris is collected and disposed of off-site.
#4	Tree length logs, mobile equipment	No formal clean up of wood debris is conducted
#5	Tree length logs, mobile equipment and overhead crane	No formal clean up of wood debris is conducted

3.1 Test and Control Sites #1

Test Site #1 was at the Weyerhaeuser Canada Ltd. Edson plant located one kilometer north of Highway 16 on the edge of the municipality of Edson (NE 23-53-17-W5M). The site is approximately 1.5 km from the MacLeod River. The soil at the site is a silty-clay till/sandy clay till and as a result, precipitation tends to runoff rather than infiltrate.

The log yards were on a clay surface and located at the northeast and northwest portions of the site with combined area of approximately 30 acres. The maximum inventory of logs in the log yard was 170,000 m^3. The logs stored on the site consisted of aspen (70%), black poplar (25%), and a small amount of conifer and birch (5%). Logs were stored for 3-4 months. Inventory was rotated fairly consistently and the log deck emptied and replenished with logs twice a year.

The entire plant site encompassed approximately 22.3 hectares (55 acres), consisting of a main production building and log storage area of 12.1 hectares (30 acres). Runoff from this site was directed via ditches and culverts to a retention pond at the southeast corner of the property. The majority of the water captured in the retention pond was used to replenish the water levels in the log thaw ponds at the northwest corner of the production building. This test site was part of the monitoring program from the beginning of the AENV program.

Control Site #1 was chosen after investigation of several creeks, streams, and surface flows north of the Edson mill site. The site, a creek, was selected based on several factors including a forested drainage area, reliability and size of flow, and accessibility. The creek crosses the Tom Hill Tower Road at 27.1 km north of Highway 748 approximately 800 m south of a "Y" intersection. The sample collection point was approximately 90 m west of the road, along a path generously marked by orange survey tape, on the north bank of the stream. The drainage area was estimated to be 30 hectares (74.1 acres).

3.2 Test and Control Sites #2

Test Site #2 was at the Sunpine Forest Products Ltd. Strachan plant located approximately 30 km SW from Rocky Mountain House (S.W. ¼ 2 & S.E. ¼ 3-38-9-W5M). The surrounding land is forest and Prairie Creek is approximately 2.5 km north of the plant. The soils consist of a silty-clay till with gravel 0.6 – 2 m beneath the surface.

The log yard covered approximately 13.6 hectares (34 acres) and had a maximum inventory of 120,000 m^3 in March and a minimum inventory of 10,000 m^3 in July. The wood species consisted primarily of pine (80%) and spruce (20%). Logs could be stored at the log yard for up to 8 months, but ideally logs would be stored for 4 months.

Runoff from the plant did not directly discharge to a surface water body, but flowed via ditches to a forested area northeast of the site. Stormwater runoff either infiltrated the soil or flowed to Prairie Creek. Sunpine improved the surface runoff control measures at their log yard in 1996 by improving the ditches and installing geogrid and erosion control berms.

Control Site #2 was chosen out of two possible sites located west of the Sunpine Strachan mill with flows discharging to Prairie Creek. The control site was located 3 km west of the Sunpine turnoff on secondary highway # 752. The control site was a small stream that flowed out of a wooded area and through a culvert under the road to another wooded area. The site was chosen based on several factors including a forested drainage area, reliability and size of flow, and accessibility.

3.3 Test and Control Sites #3

Test Site #3 was at the Weyerhaeuser Drayton Valley Oriented Strand Board (OSB) and Sawmill Plant located directly south from the Town of Drayton Valley (S.W. ¼ 8 & N.W. ¼ 5-49-7-W5M). The area surrounding the plant included a small trailer park and recreational facilities located directly north of the site. The recreational facilities included six ball diamonds, a rodeo grounds area and the Town of Drayton Valley multi-purpose Omniplex. The recreational facilities were buffered from the Town by a narrow green belt referred to as West Park Creek. The "creek" is a meandering, continuous wetland that only has significant flow during rain events and spring runoff. The West Park Creek greenbelt widens as it extends southward along the eastern boundary of the log yards. As the creek continues to flow southward it separates the Weyerhaeuser facilities from a large vacant lot and the Drayton Valley Power Limited power plant.

The log yard was 24.3 hectares (60 acres) with a clay surface approximately 4m deep and a sandy–silty clay 10m below that. Some gravel was present on the soil surface at the log decks from being tracked in from the access road on the wheels of trucks. The log yard had a maximum inventory of 270,000m^3 of conifers and 190,000m^3 of aspen at the end of March and a minimum inventory of 100,000m^3 conifers and 40,000-50,000m^3 of aspen at the end of June-July. The wood species consisted of aspen, black poplar, lodgepole pine, white spruce, alpine fir, and birch. Once a deck of logs was taken to the sawmill, the bark and green breakage are piled and later collected and burned in the tee-pee burner. The surface of the deck is then worked and repacked before logs are again stored at the same location.

Runoff from the log yard and site discharged to the West Park Creek, which is located to the east of the site. West Park Creek drains downstream into a beaver pond and from there it travels approximately 5.5 km to the North Saskatchewan River.

Control Site #3 is located approximately 1.25 km west of Lodgepole on secondary highway 620, approximately 64 metres into the forested area on the north side of the highway. The creek discharges to the Pembina River and is located in a forested area away from industrial or urban activity so that the impacts to the runoff should be due to natural processes.

3.4 Test Site #4

Test Site #4 was located at Zeidler Forest Industries Ltd.'s Mitsue Veneer Plant located within the Mitsue Industrial Park in the Municipal District of Lesser Slave Lake (NW ¼ 30-2-4-W5M). The site is located in an area of muskeg, swamp and black spruce and the soil consists of muskeg and clay that has been built up with pit run and gravel. The surrounding land use includes a variety of industries common to northern Alberta including a second sawmill, an OSB mill, a gas plant, an oil

separator/reclaimer, a chemical distribution center and two trucking firms. Mitsue Lake is approximately 1 km south and Lesser Slave River is approximately 2 km north of the facility.

The log yard area was 32.4 hectares (80 acres) and had a maximum inventory of 393,000 m^3 with wood species consisting primarily of spruce (88%), pine (7%) and balsam fir (5%). The normal deck operation consisted of logs being stored at the yard for approximately 12 months. Logs were taken to the sawmill based on the quality and size of the log. Once a deck of logs is used, debris is collected and piled for chipping or to be burned in a tee-pee burner. The surface of the deck is then worked and repacked before logs are stored on the deck.

Runoff from the log yards in the eastern portion of the site was directed off the property via ditches to a trench running parallel to the old Highway #2. The trench meanders through the bush and eventually to Lesser Slave River. The remaining runoff from the site probably percolates through the muskeg.

As previously indicated, no control site was established for Test Site #4.

3.5 Test Site #5

Test Site #5 was located at the Millar-Western Whitecourt Pulp Mill and Sawmill. The plant is located northwest of the town of Whitecourt about 100m from the banks of the confluence of the Athabasca and McLeod (NW ¼ 35-59-12-W5M). The surrounding area is residential. The soils on the site consist of 0.3 to 0.6 m of poor quality silty/sandy topsoil with some organics. In some areas the gravel is mixed with topsoil. Under the surface layer is 2 to 4 m of silt and sand. The next 2 to 6 m is coarse gravel and sand on bedrock.

The log yard had a gravel surface with an area of approximately 16.2 hectares (40 acres). The maximum inventory of logs was 750,000 m^3 in March with a minimum inventory of 150,000 m^3 in November. Softwood was the primary wood species at the site making up 61% of the wood on the site, and hardwood made up the remaining 39%. The softwood consisted of pine (34%), spruce (26%), fir (1%) and was stored in a log yard to the east end of the site. The hardwood consisted of aspen (35%), black poplar (4%) and was stored in a log yard to the north of the site. The normal deck operation consisted of logs being stored at the yard for approximately 9 months. Portal cranes were used at both log yards for transferring logs.

No specific runoff control measures were in place for the log yard. Runoff from the hardwood log yard drained to the east to ditches located parallel to the portal crane rail line, then north using natural drainage paths through to a vegetated area. Surface runoff from the west side of the softwood log yard flowed north to the hardwood log yard then followed the same path as described above. The site plan also indicated that the existing drainage course was to the southeast along the rodeo grounds and the residential area where there was a low lying area which had not been cleared of brush and trees.

4.0 OVERVIEW OF WOOD CHEMISTRY AND LOG YARD RUNOFF QUALITY

Wood is made of three major constituents, other than water, including carbohydrates, lignins, and wood extractives. The actual quantities of these constituents can vary depending on the wood species, age, geographical location and part of the tree. General characteristics can be described for softwood, defined as wood of a conifer, and hardwood, defined as wood from a deciduous tree. The following sections described these major constituents and how they relate to parameters that were analyzed in the monitoring program. Table 5 summarizes the constituents of wood, parameters that measure these constituents and data from a literature review of log yard runoff.

4.1 Carbohydrates

Carbohydrates include cellulose, hemicellulose, starch and pectin, which are all polysaccharides, i.e., long chain sugars, and water soluble wood sugars, which are typically monosaccharides, i.e., short chain sugars. Cellulose is the most abundant carbon compound in nature; it forms a skeleton of the wood cells and makes up 40% to 45% of the dry weight of wood. Hemicellulose surrounds cellulose and acts as a matrix of supporting material in the cell wall. Hemicellulose makes up 20% (dry weight) of softwoods and 15% to 30% (dry weight) in hardwoods. Carbohydrates are generally considered to be biodegradable because microorganisms can break them down into shorter fragments and wood sugars. Carbohydrates in wood can contribute to BOD, COD and TOC in log yard runoff. A literature review of log yard runoff (Alberta Environment, 1996) indicated that the chemical characteristics included BOD levels ranging from 20 to 2,230 mg/L, COD levels ranging from 11 mg/L to 6,530 mg/L and TOC levels ranging from 20 to 2,230 mg/L.

4.2 Lignins

Lignin is the second most common carbon compound in nature after cellulose and makes up 26% to 32% (dry weight) in normal softwoods and 20% to 26% (dry weight) in normal hardwoods. Lignins, like hemicellulose, surround cellulose and act as an encrusting material which bonds wood cells together into a rigid structure. Lignins are made of phenylpropanoid carbon skeleton (C_6H_5-C-C-C).

4.3 Wood Extractives

Wood extractives make up approximately 1% to 5% dry weight of wood and are wood constituents that can be extracted with organic solvents. The content of the extractives and their composition vary greatly among different wood species and also within different parts of the same tree. For example, bark amounts to approximately 10 to 15 percent of the total weight of the tree but the extractives range from 20 to 40% of the dry weight within the bark. Wood extractives can be divided into three subgroups: phenolic compounds, aliphatic compounds (mainly fats and waxes), terpenes and terpenoids.

4.4 Phenolic Compounds

Phenolic extractives function as fungicides, insecticides and antioxidants to protect the tree from decay. Phenolic extractives and related constituents can be grouped into four compounds: tannins; lignins, stilbene and tropolones. Tannins, including hydrolyzable tannins and condensed tannins are also referred to as flavonoids and are mainly found in the bark, foliage and roots of softwoods.

The tannins in wastewater generated from the removal of the bark from the log (debarking) in wood processing has been found to contribute to the toxicity of the waste stream (Field *et. al.*, 1991). The hydrogen in low molecular weight (MW) tannins bonds with proteins and can penetrate to the sensitive sites to methanogenic bacteria, fish, enzymes and fungi. Tannins of a MW greater than 3000 g mol^{-1} do not have this ability to penetrate to sensitive sites. Field *et. al.*, 1991 found that aerating coniferous bark extract, specifically from spruce and pine, caused the toxic low MW tannins to polymerize spontaneously to non-toxic darkly coloured high MW tannins. They also found that certain soil fungi are able to degrade oligomeric condensed tannins present in bark extracts. They found that the bark from three different lots of spruce had highly variable toxicity levels. They hypothesized that this difference was due to different seasons when the bark was collected and variation in the spruce tree varieties from which different samples of bark were collected.

Tannins are made of the same phenylpropanoid carbon skeleton (C_6H_5-C-C-C) as lignin. Chemical analysis is often done for the concentration of the combination of tannins and lignins. The concentration of the tannin catechin and the lignin guaiacol was measured in the log yard runoff from a dry deck at 998 µg/L and at levels ranging from 185 µg/L to 379 µg/L (Alberta Environment, 1996).

Other phenolic compounds that have been measured include para-hydroxybenzoic acid (PHBA) and are found in the sapwood and heartwood of poplars and willows. Phenols at concentrations of up to 27.3 mg/L were measured in aspen leachate (Taylor, 1992).

4.5 Aliphatic Compounds

Aliphatic compounds consist mainly of fats and waxes and are a source of stored energy for trees and are found in seed tissues (cones and fruits) and in the wood resins in softwoods and hardwoods. They are water insoluble and include fats, waxes and unsaturated fatty acids. Linoleic acid and Oleic acid were measured at 57.5 and 39.4 ppb respectively in a log yard runoff.

4.6 Terpenes and Terpenoids

Terpenes and terpenoids are water insoluble compounds that exist primarily in softwoods such as pines, spruce, larches and Douglas fir. They provide a defense against wood boring insects. After a tree is harvested resin acids can become more water soluble due to oxidation. Terpenes consist of resin acids found in the resin canals in the bark and sapwood. Resin acids are readily broken down by a number of fungal and bacterial species and are normally broken down in receiving streams and in secondary treatment facilities. Dehydroabietic acid is not the most toxic but is the most persistent resin acid. Resin acids have a relatively high affinity for solids, which over time can result in contamination of sediments. Pine trees have the highest resin content of Canadian softwoods. Fir

and spruce produce lower concentrations of resin acids. Resin acids were detected in log yard runoff at the following levels: Pimaric at 32.6 ppb, Sandaracopimaric at 24.5 ppb, Palustric 120 ppb, Isopimaric 41.9 ppb, Dehydroabietic 104 ppb, and Abietic at 409 ppb.

4.7 Inorganics

Inorganic constituents such as calcium, potassium, silicates and phosphates are found in bark at levels of two to five percent. More recently (Bailey, 1999) the cause of toxicity in storm water runoff from sawmills was discovered to be cationic metals and specifically zinc. The zinc originated from galvanized roofs and was found to be in the runoff at levels of 0.94 mg/L. This study did not include metals in the suite of parameters that were analyzed.

Table 5 Wood Chemistry & Log Yard Runoff Chemistry

Wood Constituent (% of wood dry weight)	Carbohydrates (55% - 70%)	Lignin (20 – 32%)	Wood extractives (1 – 5%)		
Components of wood constituent	Cellulose (40%) Hemicellulose (15 – 30%)	Phenylpropanoid carbon skeleton (C_6H_5-C-C-C)	Phenolic compounds	Aliphatic compounds (mainly fats &waxes)	Terpenes and Terpenoids
Amount in Softwood	60%	26% - 42%			
Amount in Hardwood	55 – 70%	20% - 28%			
Example of specific chemicals	Polysaccharides Softwoods: Glucomannans Hardwoods: glucurononxylans Monosaccharides	Phenolic acids Phenolic aldehydes Guaiacol Eugenol	Tannins (Phenylpropanoid) Gallic acid Catechol	Fatty acids Palmitic, stearic, lignieric, oleic, linoleic, linolenic	Resin acids (Pimaric, Sandaracopimaric, Dehydroabietic, Abietic, levipimaric, neoabietic, palustric, isopimaric)
Parameter(s) measuring constituent	BOD, COD, TOC	Tannins & Lignin	Tannins & Lignins Phenols	Fatty acids	Resin acids
Concentration in log yard runoff	BOD 20 to 2,230 mg/L COD 11 -6,530 mg/L TOC 20 to 2,230 mg/L.	Guaiacol 185, 379 µg/L	Catechol 998 µg/L Phenols up to 27.3 mg/L in aspen leachate	(Fatty acids in µg/L) Linoleic 57.5 Oleic 39.4	(Resin acids in µg/L) Pimaric 32.6 Sandaracopimaric 24.5 Palustric 120 Isopimaric 41.9 Dehydroabietic 104 Abietic 409

5.0 SUMMARY OF THE ANALYTICAL RESULTS

This section provides a summary of the monitoring results. Table 1 outlined the monitoring that was conducted at the different monitoring sites. Tabulated results of the individual samples taken at the test and control sites are provided in Appendix C.

5.1 Summary of All Analytical Results

Table 6 presents a summary of the chemical analysis for all the samples collected during the log yard runoff monitoring program. These results are divided into monitoring results for runoff from the test sites and from the control sites. For each chemical analysis the number of samples taken, the median, the minimum and maximum results are provided. For analytical results that were below the detection limit, the data was analyzed statistically using half the detection limit.

The results indicate that the log yard runoff consistently had a higher organic concentration as measured by BOD, COD and TOC than the control sites. Specific organic components included tannins and lignins, resin and fatty acids and phenols, which are all natural components of wood. TSS levels were also higher in log yard runoff than the control sites and may consist of wood fibres, and sediment from the activity in the log yard.

Table 6 Summary of Log Yard Runoff and Control Site Runoff Results

Parameter (Units in mg/L unless otherwise stated)	No. of Samples		Median		Minimum – Maximum	
	Log Yard	Control	Log Yard	Control	Log Yard Runoff	Control
pH (pH units)	95	12	7.3	7.6	6.2 – 9.1	6.8 – 8.4
BOD	72	9	157	2	23 – 1800	0.9 – 7.6
COD	95	12	608	45	160 – 3500	< 5 – 71
TOC	46	11	264	17.8	62 – 1080	8 – 23.2
Phenol	95	12	0.33	0.002	< 0.001– 29	< 0.001 – 0.023
TSS	89	12	85	3	< 0.4 – 3015	< 0.4 – 19
Oil & Grease	66	10	2.9	0.25	< 0.02 – 29.7	< 0.02 – 20
Tannin & Lignin	56	10	30.3	1.5	3.8 - 345	0.7 – 3.1
Resin acids (µg/L)	24	3	540	5	< 10 – 15,265	< 10 – 53.2
Fatty acids (µg/L)	24	3	119	5	< 10 – 1 218	< 10 – 1.4
Ammonia-N	29	8	0.09	0.025	< 0.05 – 1.28	<0.01 – 0.22
Phosphorous	16	3	0.82	0.05	0.15 – 3.0	0.014 – 0.083

Table 7 presents a summary of the bioassay results for all the samples collected. For each bioassay test the number of samples tested, the median, and the minimum and maximum results are provided. The median values for the bioassay test using Rainbow trout exposed to the test solution for a 96 hour period indicate that log yard runoff has the potential to be acutely lethal at 70% concentration. Median values for the *daphnia magna* bioassays were 100%. The microtox ™ test indicated a median value of 46%. The range of toxicity results for the log yard samples indicates that runoff can vary widely in toxicity to both Rainbow Trout and *daphnia magna*, from completely non-toxic at 100% concentrations to LC50's of relatively low concentrations. The control samples showed less variability and lower toxicity although, as shown in the table, the number of samples was limited.

Table 7 Summary of Bioassay Results for Log Yard Runoff and Control Site Samples

Bioassay Testing	No. of Samples		Median	Minimum – Maximum	
	Log Yard	Control	Log Yard	Log Yard Runoff	Control
Rainbow Trout LC50 @ 96hrs	17	2	70%	7.1% – >100%	100%
Daphnia Magna LC50 @ 48 hrs	15	3	> 100%	8.8% – > 100%	100%
Daphnia Magna EC50 @ 48 hrs	14	3	> 100%	8.8% – >100%	100%
Microbiological Analysis Report Toxicity Testing	59	6	46%	1.5% - > 100%	>90% - >100%

5.2 Test Site #1 Results

A summary of the chemical analysis results of Test Site #1 is provided in Table 8. Samples were collected of the runoff entering the pond, of the stormwater in the pond and of the runoff at the pond outlet. Of the five sites this was the most closed system, i.e., all runoff was directed to the retention pond and, as described in Section 3, precipitation tended to run overland rather than infiltrate. The ratio of logs stored to log yard area was high at this site compared to the other sites. The median phenol level at this test site appeared to be considerably higher than the median for all test sites in Table 6.

Table 8 Summary of Test Site #1 Log Yard Runoff Results

Parameter (Units in mg/L unless otherwise specified)	No. of Samples	Median	Minimum – Maximum
pH (pH units)	32	7	6.3 – 8
BOD	20	371	110 – 1800
COD	32	750	300 – 3500
TOC	24	291	72 – 1080
Phenol	32	2.7	0.06 – 21.1
TSS	32	70.5	33 – 596
Oil & Grease*	20	2.25	0.4 – 15.4
Tannin & Lignin	20	34.8	3.8 – 345
Resin acids (µg/L)	4	57	25 – 74
Fatty acids (µg/L)	4	154	100 – 1218
Ammonia-N*	12	0.1	<0.05 – 1.28
Phosphorous as P	4	0.89	0.52 – 1.28

* Database for ammonia and oil and grease includes non-detection levels.

5.3 Test Site #2 Results

Results of samples collected at Test Site #2 are provided in Table 9. The wood species consisted of approximately 80% pine and 20% spruce. These samples appeared to be the most acidic of all the samples collected and of all the sites generally had the highest concentrations for the parameters analyzed. All samples were taken during the springtime.

Table 9 Summary of Test Site #2 Log Yard Runoff Quality

Parameter (Units in mg/L unless otherwise specified)	No. of Samples	Median	Minimum – Maximum
pH (pH units)	10	6.7	6.2 – 7.4
BOD	3	651	428 – 983
COD	10	1715	600 – 2860
TOC	9	455	244 – 830
Phenol	10	1.91	0.104 – 6.22
TSS	10	257	42 – 1150
Oil & Grease	5	19.7	9 – 29.7
Tannin & Lignin	4	105	50.5 – 165
Resin acids (µg/L)	2		2185 – 2195
Fatty acids (µg/L)	2		115 – 363
Ammonia-N	4	0.09	<0.005 – 0.23
Phosphorous as P	1		0.377

5.4 Test Site #3 Results

Table 10 summarizes the analytical results of the samples taken at Test Site #3. Samples were taken from two locations, from a culvert that drained runoff from log yards containing both aspen and conifer species, and from a culvert that drained log yards containing only conifer logs. The combination of aspen and conifer logs consumed 90% of the area of the log yard with the remainder being only conifer logs. There appears to be a difference between the samples taken from the conifer log yard compared to samples taken from the aspen/conifer log yard. An analysis was conducted of the two data sets and the results of this analysis are provided in the next section.

Table 10 Summary of Test Site #3 Log Yard Runoff Quality

Parameter (Units in mg/L unless otherwise specified)	No. of Samples		Median			Minimum – Maximum	
	Aspen/ conifer	Conifer	Aspen/ conifer	Conifer	All	Aspen/conifer	Conifer
pH (pH units)	14	16	7.3	7.5	7.5	6.4 – 9.1	6.5 – 8.2
BOD	12	14	286	137	167	69 – 1330	36 – 304
COD	14	16	1050	590	610	410 – 3030	260 – 800
TOC	3	4	165	154	165	126 – 945	129 – 284
Phenol	14	16	0.96	0.047	0.09	0.056 – 9.8	0.001 – 29
TSS	11	13	224	160	192	0.4 – 3015	0.4 – 1485
Oil & Grease	8	10	6.7	5.8	5.8	2– 25	0.7 – 22
Tannin & Lignin	12	14	58.4	22.5	32	11.4 – 178	10.5 – 59
Resin acids (µg/L)	6	5	590	3400	960	10.5 – 15265	560 – 4341
Fatty acids (µg/L)	6	5	283	196	196	0 – 713	118 – 470
Ammonia-N	3	4	0.11	0.09	0.09	0.06 – 0.17	<0.05 – 0.3
Phosphorous as P	3	3	1.01	1.03	1.02	0.23 – 3.01	0.779 – 1.33

5.5 Test Site #4 Results

Results for Test Site #4 are provided in Table 11 (* Indicates non detectable concentrations found and included in statistical analysis). The wood species at the site consisted, on average, of approximately 88% spruce, 7% pine and 5% balsam fir. The samples were taken primarily in the spring and summer of 1997. The results of samples collected at this site appeared to have the lowest concentrations for the parameters analyzed of all the sites.

Table 11 Summary of Test Site #4 Log Yard Runoff Quality

Parameter (Units in mg/L unless otherwise specified)	No. of Samples	Median	Minimum – Maximum
pH (pH units)	13	7.4	6.9 – 7.4
BOD	13	43	23 – 104
COD	13	270	160 – 350
TOC	4	82	62 – 114
Phenol	13*	0.017	0.001 – 0.24
TSS	13*	3	<0.4 – 13
Oil & Grease	13*	1	1 – 4
Tannin & Lignin	4	7.7	4.5 – 8.4
Resin acids (µg/L)	4	320	174 – 474
Fatty acids (µg/L)	4	24.8	8 – 60
Ammonia-N	4	0.06	<0.05 – 0.29
Phosphorous as P	4	0.18	0.15 – 0.3

5.6 Test Site #5 Results

Table 12 provides a summary of the results of analysis of samples collected at Test Site #5. This site was similar to Test Site #5 in that the samples were taken primarily in the spring of 1997. The results were also similar to Test Site #5 in that the concentrations for the parameters analyzed were relatively low compared to the other sites.

Table 12 Summary of Test Site #5 Log Yard Runoff Quality

Parameter (Units in mg/L unless otherwise specified)	No. of Samples		Median			Minimum – Maximum	
	Aspen	Conifer	Aspen	Conifer	All	Aspen	Conifer
pH (pH units)	5	5	7.5	7.4	7.5	7.4 – 7.9	7.3 – 7.6
BOD	5	5	63	176	99	54 – 84	114 – 258
COD	5	5	400	700	545	380 – 136	550 – 1280
TOC	1	1				540	201
Phenol	5	5	0.067	0.047	0.05	0.047 – 0.069	0.028 – 0.057
TSS	5	5	248	124	165	144 – 900	62 – 755
Oil & Grease	5	5	<2	4.8	3.2	<2 – 3.4	<1 – 6
Tannin & Lignin	1	1				12.8	15.5
Resin acids (µg/L)	1	1				795	1065
Fatty acids (µg/L)	1	1				93	149
Ammonia-N	1	1				<0.05	<0.05
Phosphorous as P	1	1				2.61	0.54

6.0 DATA ANALYSIS

A nonparametric test called the Wilcoxon-Mann-Whitney Rank-Sum Test (W-M-W Test) for independent samples was used in the data analysis. The objective of the W-M-W Test is to detect whether two sample sets and their underlying populations are centered differently. If the sample sets come from the same population, i.e., if the runoff from one site is the same as the runoff from another site, then the results of the chemical analysis should be similar. In the first step, monitoring results from the test sites to be compared are combined and jointly ranked from smallest to largest. If there is no difference in the central tendency, the average combined rank of the monitoring results from each test site will be identical. Nonparametric tests are used when the population distribution of a sample set is not known or when the population distribution set is not normal. This is not uncommon in experimental work. The analysis compared runoff quality from the control sites to the test sites, from the test sites to typical limits and also compared the runoff quality from the test sites to each other to assess how the site characteristics may have affected the runoff quality.

6.1 Control Site vs. Test Site Runoff Quality

To determine if there was a significant difference between the runoff quality from the test sites and the control sites, the data was analyzed using the W-M-W Test. The monitoring results from the three test and control sites that were used in the analysis are provided in Appendix C, Table C-9. The test sites had a mixture of deciduous and coniferous logs. The forested area of the control sites was a mixture of coniferous and deciduous trees. Table 13 summarizes the minimum, maximum, average, median and number of samples in the data set.

The W-M-W test indicated that there was a significant difference between the test and control site quality. Graphs of the pH, BOD, COD, phenol, TSS and tannin and lignin concentrations in the runoff from the control and test sites are shown on Figure 2. The pH of the control sites tended to be slightly more alkaline with pH ranging from 6.8 to 8.4 compared to test site pH range of 6.31 to 7.93. The highest BOD measured at the control site was 7.6 mg/L compared to 988 mg/L measured at the test site. COD, phenol, TSS and tannin and lignins showed similar trends in that the test site runoff had significantly higher concentrations than the control sites.

Table 13 Summary of Control Site and Test Site Runoff Quality

Parameter	Location	Minimum	Maximum	Average	Median	Number of Samples
pH	Control	6.8	8.4		7.6	12
	Test	6.31	7.7		7.1	11
BOD	Control	0.9	7.6	2.4	2	9
	Test	77	983	348	205	7
COD	Control	<5	71	39	45	12
	Test	340	2860	1153	920	11
Phenol	Control	<0.001	0.023	0.006	0.002	12
	Test	<0.001	6.22	1.7	0.03	11
TSS	Control	<0.4	19	6	3	12
	Test	0.4	1420	400	211	11
Tannin &	Control	0.7	3.1	1.7	1.5	10
Lignin	Test	11.4	165	54	40	8

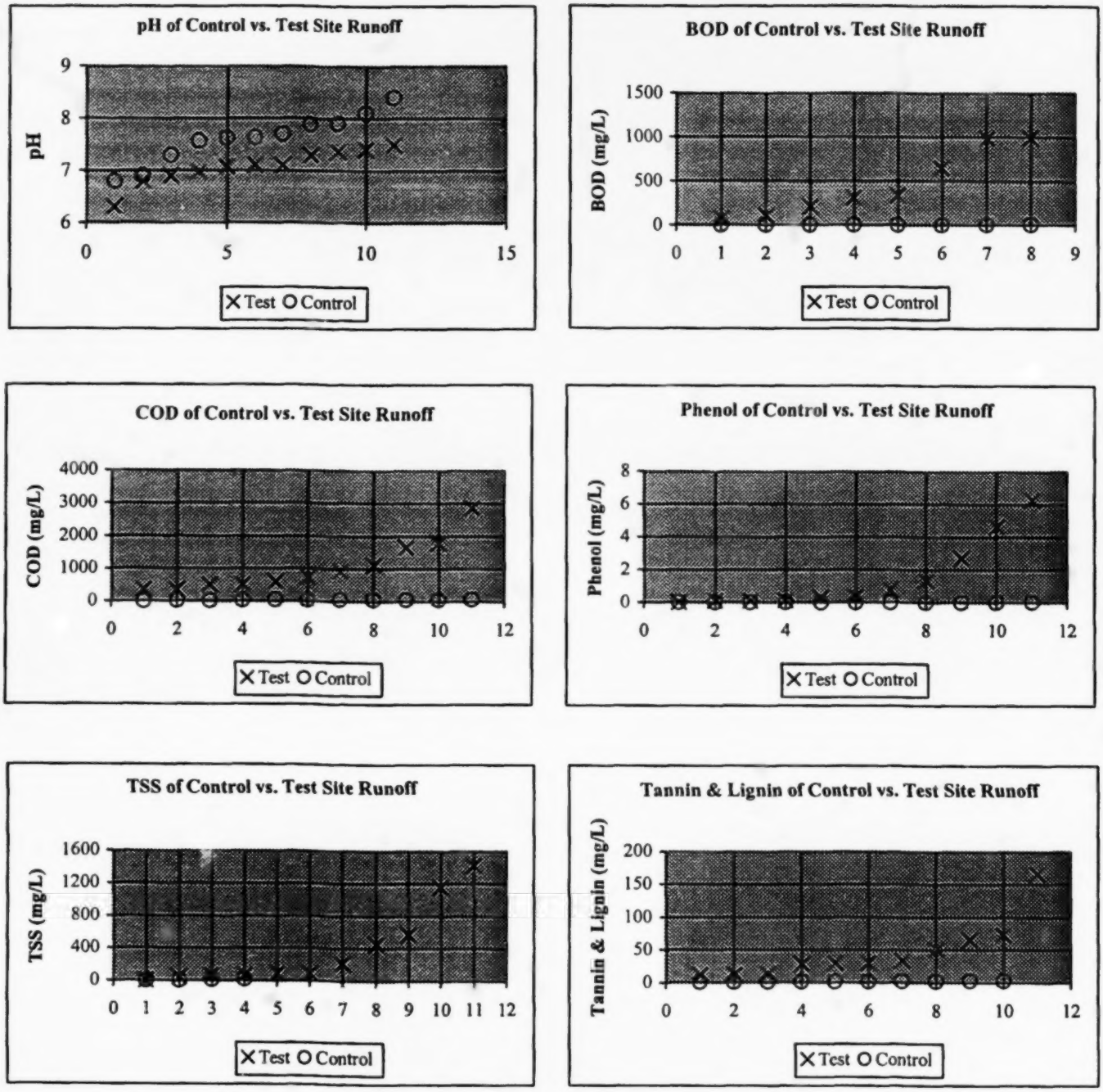


Figure 2 Comparison of Runoff Quality from Control and Test Sites

6.2 Comparison of Log Yard Runoff Quality to Typical Stormwater Limits

Stormwater limits have been specified for individual industrial facilities when a need has been identified. Limits for industrial facilities are set through EPEA approvals. Typically, stormwater limits have been set for pH, COD and TSS. The pH of the runoff is to be greater than 6.0 and less than 9.5, a COD level of no greater than 100 mg/L and a TSS level of no greater than 50 mg/L. Table 14 summarizes the number of test samples the statistic is based on, the range of concentrations from minimum to maximum, average, median, 75th percentile and the associated typical limit for that substance.

Table 14 Summary of Test Site Runoff Quality to Typical Limits

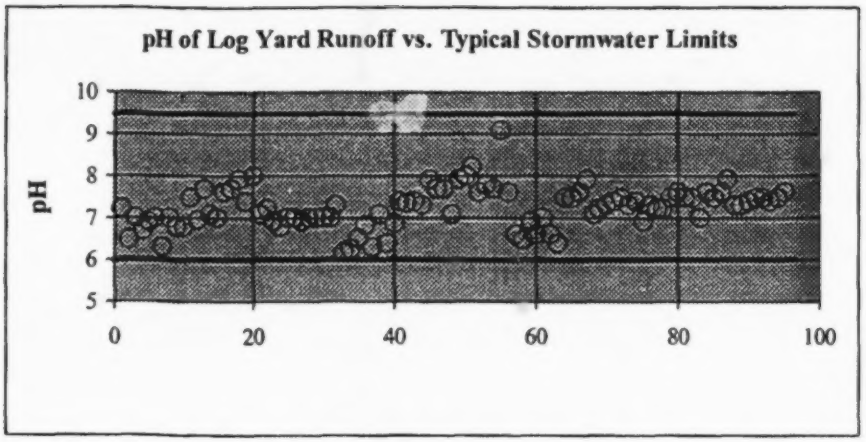
Parameter	Number of Test Samples	Range (Minimum - Maximum)	Average	Median	75th Percentile	Typical Limit
pH	95	6.17 – 9.1		7.3	7.5	6.0 – 9.5
COD (mg/L)	95	160 – 3,500	867	608	920	100
TSS (mg/L)	89	0.2 - 3015	248	85	248	50

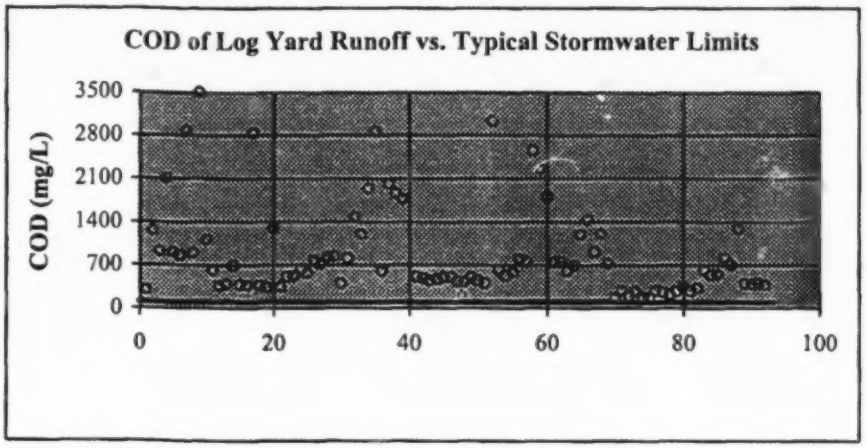
Figure 3 presents plots of pH, COD and TSS of the log yard runoff quality for all the test sites compared to the typical storm water limits. The pH of the log yard runoff was consistently within the typical limits but COD consistently exceeded the typical 100 mg/L limit. There was a wide range in the TSS data with 55 percent of the TSS concentrations below 100 mg/L. The highest concentration was 3,015 mg/L. A log scale was used to present the TSS data in Figure 3.

6.2.1 Comparison of Log Yard Runoff Quality between Sites

To determine if there is a significant difference between the runoff quality from the test sites and the control sites, the data was analyzed using the W-M-W Test. If there is a significant difference between the analytical results from the different test sites then the question is, could this difference be attributed to one or more factors? The main difficulty in this analysis, as indicated previously, is that the test sites are not controlled, i.e., there are many factors that are specific to each site which may not have been taken into consideration. The best that this analysis can provide is that certain factors may contribute to the runoff quality. Some of the factors that have been identified as potentially affecting the runoff quality include:

- The size of the log yard and the amount of logs stored, and therefore the ratio of the maximum inventory of logs to the log yard area;
- The predominant wood type stored at the site, for example coniferous or deciduous;
- The management practices (management of runoff at the test site, the way the logs are stored, clean-up of debris, etc.), and
- Differences in soil and topography of the various log yards.





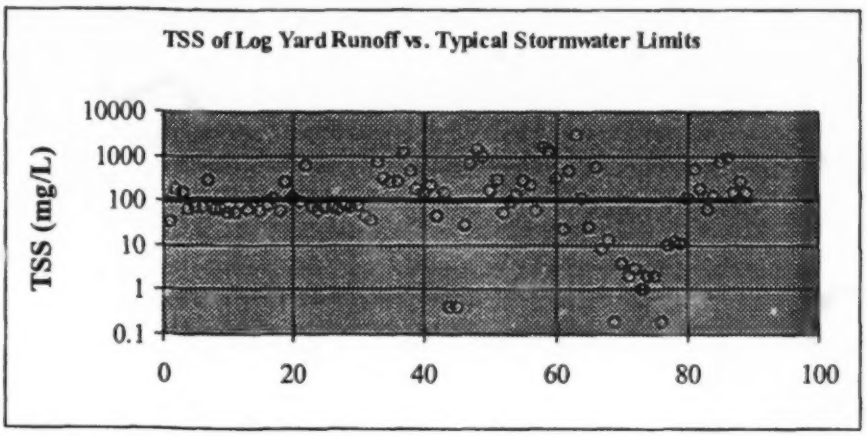


Figure 3 **Comparison of Log Yard Runoff Quality with Typical Stormwater Limits**

Table 15 provides the median values for each of the water quality parameters for each site. The number of samples this value is based on is shown in brackets next to the median value. For Test Site #1, only samples collected from the pond outlet were used to compare with other test sites.

Table 15 Median Value for Each Test Site's Log Yard Runoff Quality

Parameter (Units in mg/L unless otherwise specified)	Test Site #1	Test Site #2	Test Site #3	Test Site #4	Test Site #5	All
pH	7 *(32)*	6.7 *(10)*	7.5 *(30)*	7.4 *(13)*	7.5 *(10)*	7.3 *(94)*
BOD	371 *(20)*	651 *(3)*	167 *(26)*	43 *(13)*	99 *(10)*	156 *(71)*
COD	750 *(32)*	1715 *(10)*	610 *(30)*	270 *(13)*	545 *(10)*	604 *(94)*
TOC	292 *(24)*	455 *(9)*	165 *(7)*	82 *(4)*	135, 201 *(2)*	244 *(45)*
Phenol	2.7 *(32)*	1.91 *(10)*	0.093 *(7)*	0.017 *(13)*	0.05 *(10)*	0.56 *(92)*
TSS	70 *(32)*	257 *(10)*	192 *(24)*	4 *(13)*	165 *(10)*	93 *(86)*
Oil & Grease	2.25 *(20)*	19.7 *(5)*	5.8 *(18)*	3 *(13)*	3.2 *(10)*	3.9 *(49)*
Tannin & Lignin	34.8 *(20)*	105 *(4)*	32 *(26)*	7.7 *(4)*	13, 16 *(2)*	28.9 *(55)*
Resin acids (µg/L)	57 *(4)*	2185, 2195 *(2)*	960 *(11)*	320 *(4)*	795, 1064 (2)	497 *(22)*
Fatty acids (µg/L)	154 *(4)*	115, 363 *(2)*	196 *(11)*	25 *(4)*	93, 149 (2)	119 *(22)*
Ammonia-N	0.1 *(12)*	0.09 *(3)*	0.09 *(7)*	0.06*(4)*	<0.05 (2)	0.11 *(21)*
Phosphorous	0.89 *(4)*	0.37 (1)	1.02 *(6)*	0.18 *(4)*	0.5, 2.6 *(2)*	0.81 *(16)*

The results of the W-M-W test and graphs comparing the runoff quality at the five test sites to each other are provided for the individual parameters including pH, BOD, COD, phenol, TSS, tannin and lignin, resin and fatty acids and oil and grease. This section closes with a summary of the W-M-W test results and an assessment of the factors that may be affecting the runoff quality.

6.2.2 pH of Test Sites Log Yard Runoff

The W-M-W test results are summarized below in Table 16. These results indicate that the pH of log yard runoff from sites 1 and 2 was significantly different from sites 3, 4 and 5. There is not a significant difference between the Test Site #1 and #2 pH or between Test Sites #3, #4 and #5. These results are consistent when comparing the median pHs of the test sites. Test Sites #1 and # 2 had similar soil types however the similarities end there. Figure 4 plots the pH for the five sites.

Table 16 Summary of W-M-W Test Results Comparing Test Site Runoff pH

Test Site	1	2	3	4	5
1		No significant difference	Significant difference	Significant difference	Significant difference
2			Significant difference	Significant difference	Significant difference
3				No significant difference	No significant difference
4					No significant difference
# Samples	17	10	30	13	10
Range in pH	6.6 – 7.9	6.2 – 7.4	6.4 - 9.1	6.9 – 7.4	7.4 – 7.9
Median pH	6.9	6.7	7.5	7.4	7.5

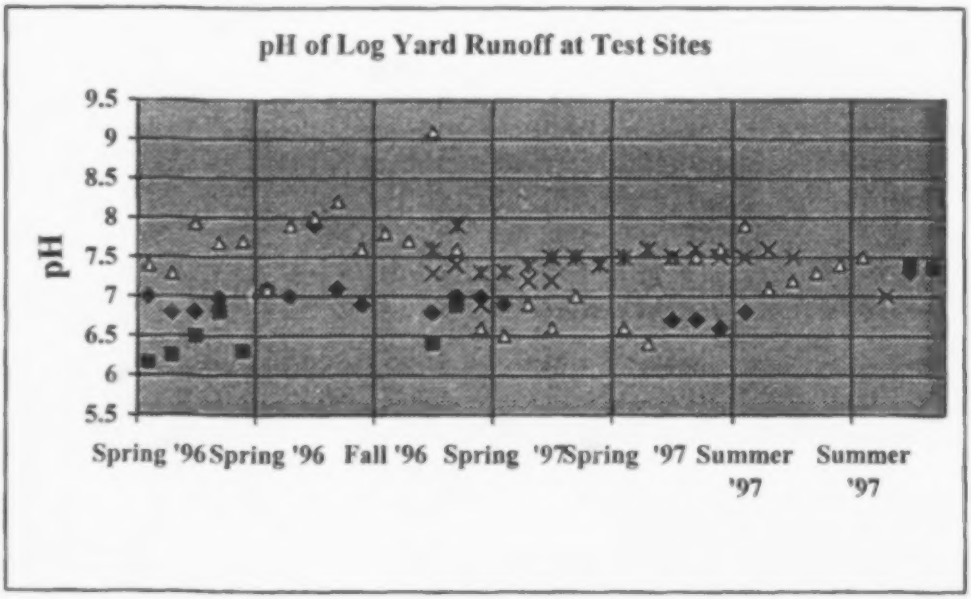


Figure 4 pH of the Log Yard Runoff at the Test Sites

6.2.3 BOD of Test Sites Log Yard Runoff

The W-M-W test results are summarized below in Table 17. There was insufficient data to compare the BOD of log yard runoff of test site 2 with any of the other test sites using the W-M-W test. The W-M-W test results of the BOD of the log yard runoff of the remaining test sites indicate that the BOD of log yard runoff from sites 1, 4 and 5 was significantly different from each other. However, there was not a significant difference between the BOD of the log yard runoff from test site 3 and 5. Sites 3 and 5 were similar in the type of tree species at the site but otherwise did not have similarities. Figure 5 plots the BOD for the five sites.

Table 17 Summary of W-M-W Test Results Comparing Test Site Runoff BOD

Test Site	1	2	3	4	5
1		Not enough data	Significant difference	Significant difference	Significant difference
2			Not enough data	Not enough data	Not enough data
3				Significant difference	No significant difference
4					Significant difference
# Samples	17	3	26	13	10
Range	110 – 988	428 – 984	36 – 1330	23 - 104	54 – 258
Median	330		167	43	99

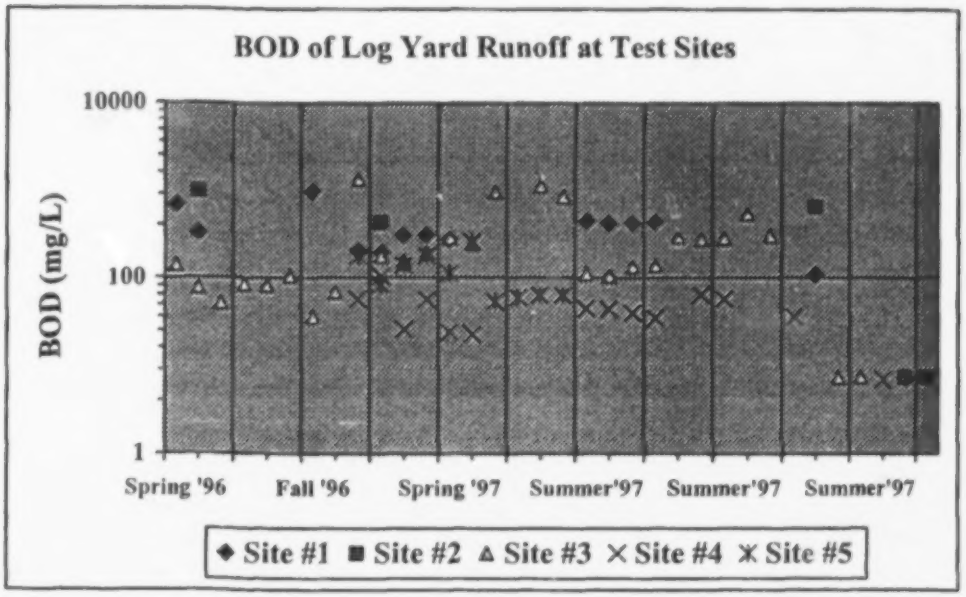


Figure 5 BOD of the Log Yard Runoff at the Test Sites

6.2.4 COD of Test Sites Log Yard Runoff

The W-M-W test results are summarized below in Table 18. The W-M-W test comparing the COD of the log yard runoff indicates that there was no significant difference between site 1 and 5 and site 3 and 5. There was a significant difference in the COD in the log yard runoff between sites 1 and 2 and 4. Sites 1, 3 and 5 were similar in that all three sites had poplar but otherwise there were no additional similarities. Figure 6 is a plot of the log yard runoff COD.

Table 18 Summary of W-M-W Test Results Comparing Test Site Runoff COD

Test Site	1	2	3	4	5
1		Significant difference	Significant difference	Significant difference	No Significant difference
2			Significant difference	Significant difference	Significant difference
3				Significant difference	No significant difference at 0.01*
4					Significant difference
# Samples	17	10	19	13	10
Range	340 – 1110	600 – 2860	260 – 3030	160 – 350	380 – 1280
Median	640	1715	500	270	545

* Significant difference at 0.05

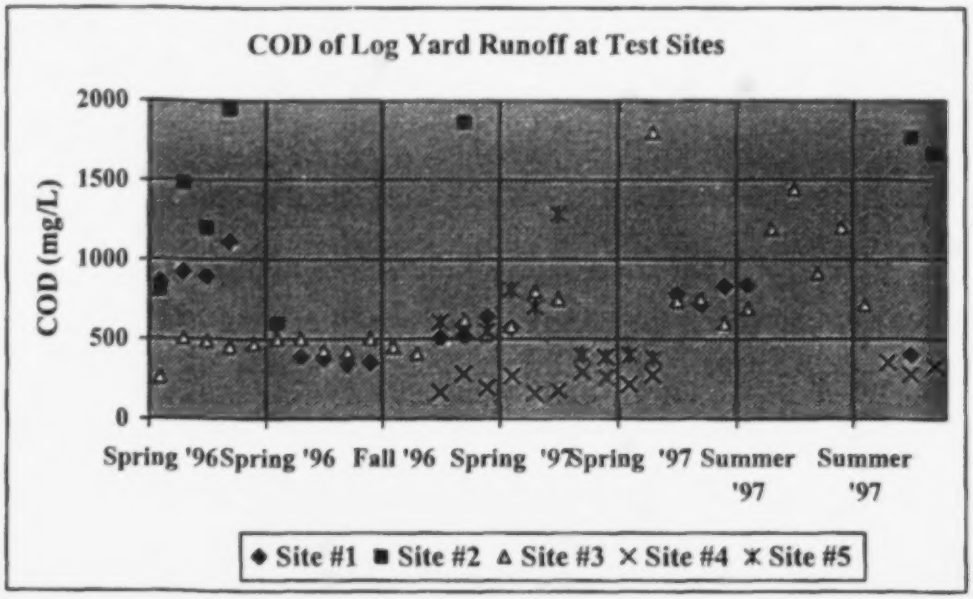


Figure 6 COD of the Log Yard Runoff at the Test Sites

6.2.5 Phenol of Test Sites Log Yard Runoff

The W-M-W test results are summarized below in Table 19. The W-M-W test comparing the phenol concentrations of the log yard runoff indicate that there was no significant difference between Test Site #1 and #2 and Test Site #3 and #5 and #4 and #5. When comparing the median phenol concentration levels, Test Sites #1 and #2 had the highest levels at 2.7 and 1.9 mg/L respectively compared to the rest of the test sites. Test Sites #1 and #2 were only similar in soil type, i.e., a silty / clay till. Test Sites #3 and #5 also have comparable levels at 0.09 mg/L and 0.05 mg/L. Test sites #3 and #5 had a similar mix of conifer and deciduous tree species. Test site #4 and #5 also had comparable levels at 0.017 mg/L and 0.05 mg/L. Test site #4 and #5 were similar by having no defined runoff path. There was a significant difference in the phenol concentrations in the log yard runoff between Test sites #1 and #3, #4, #5.

Table 19 Summary of W-M-W Test Results Comparing Test Site Runoff Phenol

Test Site	1	2	3	4	5
1		No significant difference	Significant difference	Significant difference	Significant difference
2			Significant difference	Significant difference	Significant difference
3				Significant difference	No Significant difference
4					No Significant difference
# Samples	17	10	30	13	10
Range	0.06 – 21.1	0.104 – 6.22	<0.001 – 29	0.001 – 0.24	0.028 – 0.069
Median	2.7	1.9	0.09	0.017	0.05

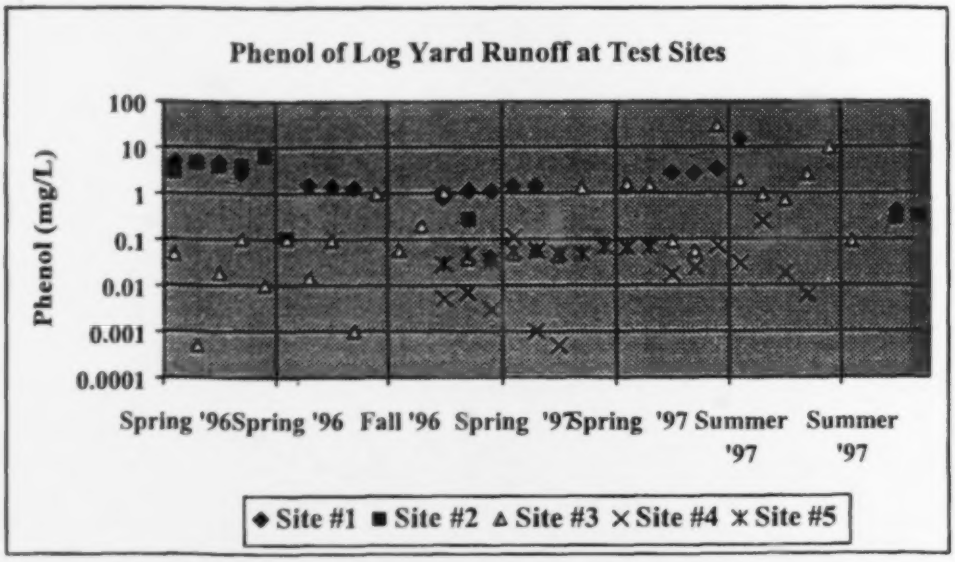


Figure 7 Phenol of the Log Yard Runoff at the Test Sites

6.2.6 TSS of Test Sites Log Yard Runoff

The W-M-W test results are summarized below in Table 20. The W-M-W test comparing the TSS concentrations of the log yard runoff indicate that there was no significant difference between sites 2 and 3 and sites 2 and 5 and sites 3 and 5. When comparing the median TSS concentration levels test sites 2, 3 and 5 had the highest levels at 257, 192 and 165 mg/L respectively. The expectation would be that either the sites with comparable TSS levels would have similar characteristics in terms of soils, log yard management practices or that the rainfall intensity at sampling times were similar. There are no definitive similarities of these three sites based on the information that has been recorded.

Table 20 Summary of W-M-W Test Results Comparing Test Site Runoff TSS

Test Site	1	2	3	4	5
1		Significant difference	Significant difference	Significant difference	Significant difference
2			No Significant difference	Significant difference	No Significant difference
3				Significant difference	No Significant difference
4					Significant difference
# Samples	17	10	26	13	10
Range	38 – 96	42 - 1150	0.4 – 3015	0.2 - 13	6.2 – 900
Median	68	257	192	3	165

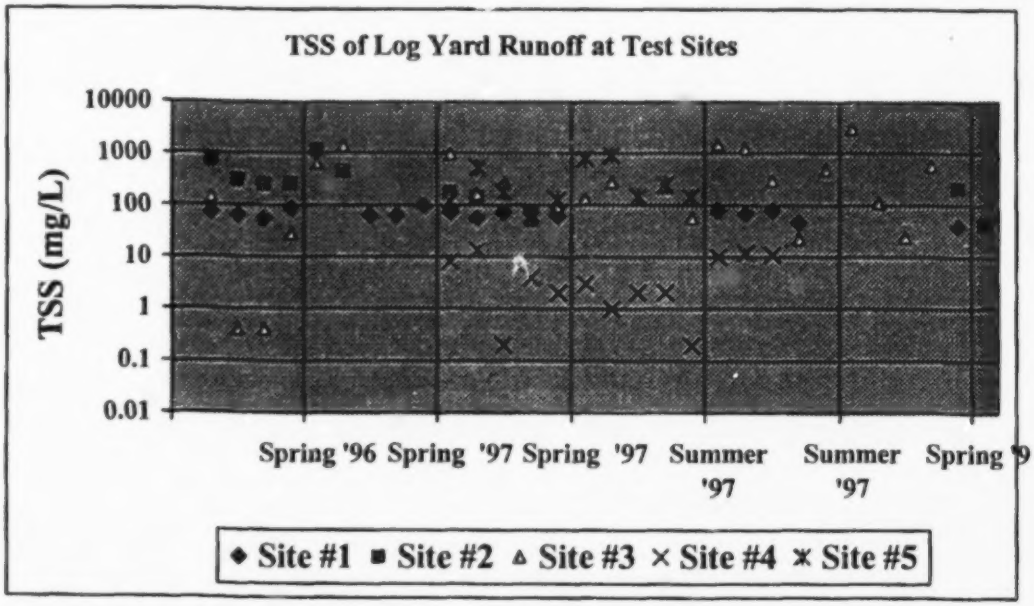


Figure 8 TSS of the Log Yard Runoff at the Test Sites

6.2.7 Oil & Grease of Test Sites Log Yard Runoff

The W-M-W test results are summarized below in Table 21. The W-M-W test comparing the Oil & Grease concentrations of the log yard runoff indicate that there was no significant difference between sites 1 and 4, sites 1 and 5, and 4 and 5. The median oil and grease levels at test sites 1, 4 and 5 were 1.25 mg/L, 1.0 mg/L and 0.25 mg/L. There are no definitive similarities of these three sites based on the information that has been recorded.

Table 21 Summary of W-M-W Test Results Comparing Test Site Runoff Oil & Grease

Test Site	1	2	3	4	5
1		Significant difference	Significant difference	No significant difference	No significant difference
2			Significant difference	Significant difference	Significant difference
3				Significant difference	Significant difference
4					No significant difference
# Samples	14	5	18	13	10
Range	0.4 – 4.8	9 – 29.7	0.7 – 25	1 - 4	0.2 – 20
Median	1.25	19.7	5.8	1.0	0.25

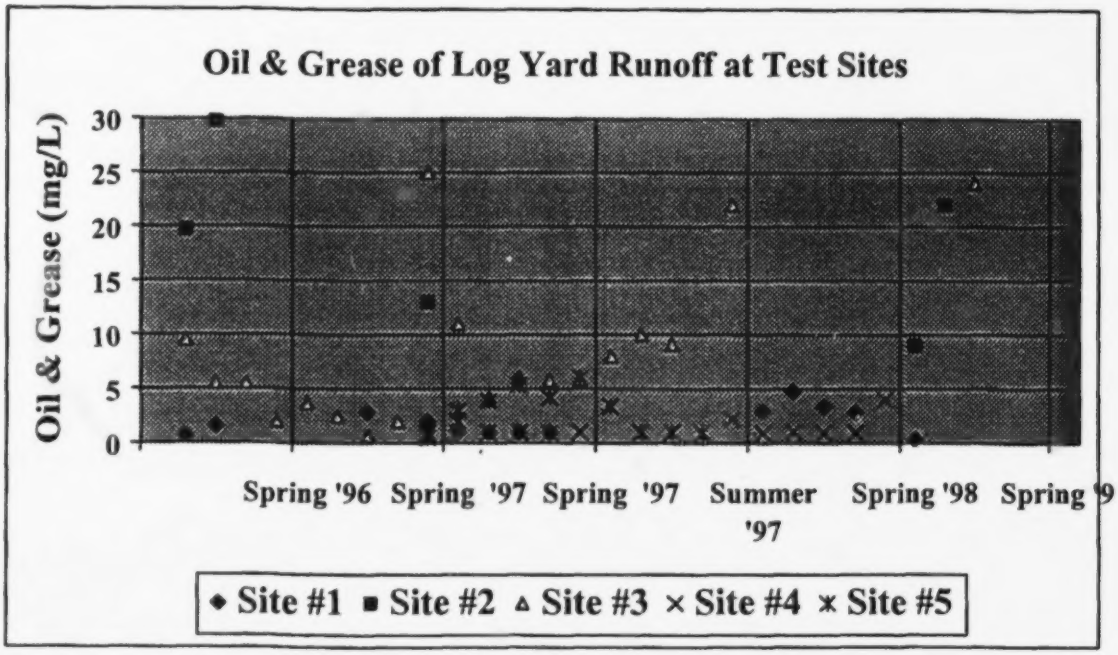


Figure 9 Oil & Grease of the Log Yard Runoff at the Test Sites

6.2.8 Tannin & Lignin of Test Sites Log Yard Runoff

The W-M-W test results are summarized below in Table 22. There was insufficient data to compare the tannin and lignin concentrations in the log yard runoff at Test Site #5 to the rest of the test sites. The W-M-W test comparing the tannin & lignin concentrations of the log yard runoff indicate that there was no significant difference between sites 1 and 2 and sites 1 and 3. There are no definitive similarities of these three sites based on the information that has been recorded.

Table 22 Summary of W-M-W Test Results Comparing Test Site Runoff Tannin & Lignin

Test Site	1	2	3	4	5
1		No significant difference	No significant difference	Significant difference	Not enough data
2			Significant difference	Significant difference	Not enough data
3				Significant difference	Not enough data
4					Not enough data
# Samples	13	4	26	4	2
Range	3.8 – 79	50.5 - 165	10.5 – 178	4.5 – 8.4	12.8 – 15.5
Median	28.9	105	32.2	7.7	Not enough data

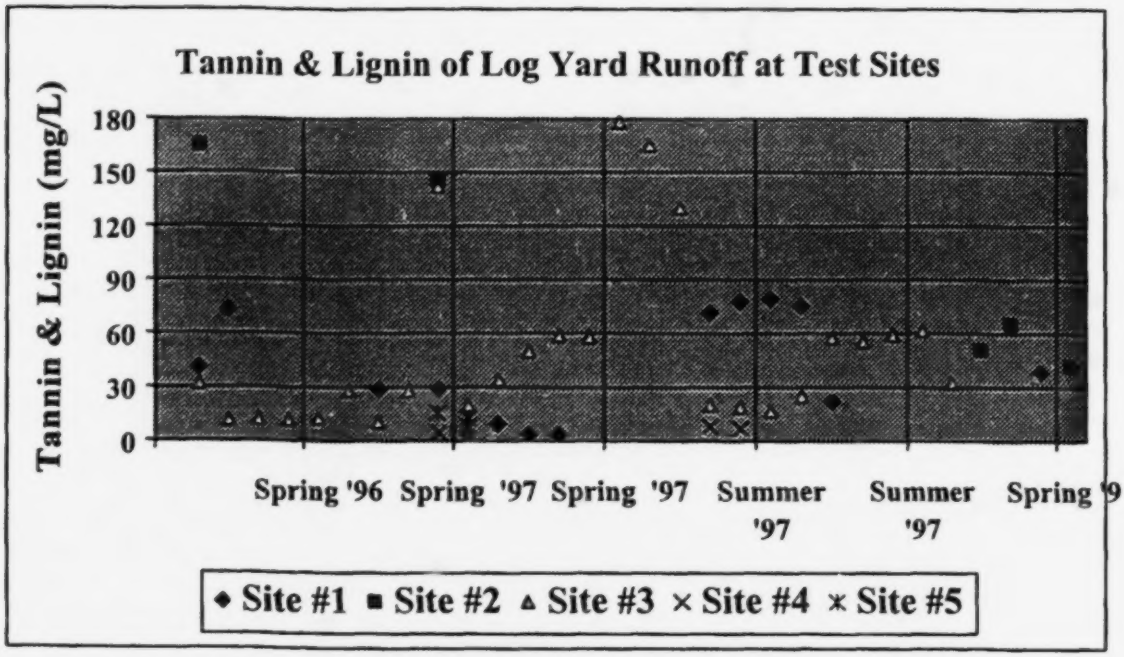


Figure 10 Tannin & Lignin of the Log Yard Runoff at the Test Sites

6.2.9 Fatty Acids and Resin Acids of Test Sites Log Yard Runoff

A graph has not been provided for the fatty acids and resin acids since for three of the five test sites insufficient samples were taken for statistical analysis. Tables 23 and 24 below summarize the data and the results of the W-M-W testing.

Table 23 Summary of W-M-W Test Results Comparing Test Site Runoff Fatty Acids

Test Site	1	2	3	4	5
1		Not enough data	No significant difference	No significant difference	Not enough data
2			Not enough data	Not enough data	Not enough data
3				Significant difference	Not enough data
4					Not enough data
# Samples	4	2	10	4	2
Range	100 – 1218	115 – 363	79 – 713	8.1 – 59.6	93 – 149
Median	154	N/A	196	24.8	Not enough data

Table 24 Summary of W-M-W Test Results Comparing Test Site Runoff Resin Acids

Test Site	1	2	3	4	5
1		Not enough data	Significant difference	No significant difference	Not enough data
2			Not enough data	Not enough data	Not enough data
3				Significant difference	Not enough data
4					Not enough data
# Samples	4	2	11	4	2
Range	25 – 74	2185 - 2195	10.5 – 15,265	174 - 474	796 – 1065
Median	57	Not enough data	960	320	Not enough data

6.2.10 Ammonia-N and Phosphorus of Test Sites Log Yard Runoff

A graph has not been provided for the ammonia-N and phosphorous since for two of the five test sites insufficient samples were taken for statistical analysis. Tables 25 and 26 below summarize the data and the results of the W-M-W testing.

Table 25 Summary of W-M-W Test Results Comparing Test Site Runoff Ammonia-N

Test Site	1	2	3	4	5
1		No significant difference	No significant difference	No significant difference	Not enough data
2			No significant difference	No significant difference	Not enough data
3				No significant difference	Not enough data
4					Not enough data
# Samples	12	4	7	4	2
Range	<0.05 – 1.28	<0.005 – 0.23	<0.05 – 0.3	<0.05 – 0.3	<0.05
Median	0.1	0.09	0.09	0.06	Not enough data

Table 26 Summary of W-M-W Test Results Comparing Test Site Runoff Phosphorous

Test Site	1	2	3	4	5
1		Not enough data	No significant difference	Significant difference	Not enough data
2			Not enough data	Not enough data	Not enough data
3				Significant difference	Not enough data
4					Not enough data
# Samples	4	1	6	4	2
Range	0.52 – 1.28	0.377	0.231 – 3.01	0.15 – 0.3	0.54, 2.61
Median	0.9	Not enough data	1.02	0.18	Not enough data

6.2.11 Assessment of the Factors Effecting the Log Yard Runoff Quality

Table 27 summarizes the results of the W-M-W test by providing the median values for the log yard runoff quality and the ranking of the test sites according to the concentrations (highest to lowest) for the specified parameters. If the W-M-W test indicated that there was not a significant difference between test sites for a specific parameter then the test sites were considered equivalent.

Table 27 Median Value of Log Yard Runoff Quality from Test Sites & their Rankings

Test Site	pH	BOD	COD	Phenol	Tannins & Lignins	Oil & Grease	TSS	Fatty Acids	Resin Acids	N	P
1	6.9	330	640	2.9	28.9	1.25	68	154	57	0.1	0.9
2	6.7	Not enough data	1715	1.9	105	19.7	257	Not enough data	Not enough data	0.1	Not enough data
3	7.5	167	500	0.09	32.2	5.8	192	196	960	0.1	1.0
4	7.4	43	270	0.017	7.7	1.0	3	24.8	320	0.6	0.2
5	7.3	99	545	0.05	Not enough data	0.25	165	Not enough data	Not enough data	Not enough data	Not enough data
Ranking of the Test Sites according to their Median Value and the W-M-W Test											
Highest	3 =4 = 5	1	2	1 = 2	2 = 1	2	2 = 3= 5	3=1	3		1=3
Mid-Range		3=5	1 = 3= 5	3	1 = 3	3	1			1=2= 3=4	
Lowest	1 = 2	4	4	4 =5	4	1=4=5	4	4=1	4 = 1		4

Several factors were previously identified as potentially affecting the runoff quality. These factors are summarized in Table 28 below. Note that, as previously discussed, the best this analysis can provide is that certain factors may contribute to the runoff quality.

Table 28 Site Characteristics of each Test Site

Site Characteristic	Test Site #1	Test Site #2	Test Site #3	Test Site #4	Test Site #5
Log yard area	20	34	60	80	40
Max. inventory	170,000	120,000	360,000	390,000	750,000
Predominant tree species	95% deciduous (poplar)	100% coniferous (80% pine 20% spruce)	59% conifers (pine, spruce, fir) 41% deciduous (poplar, birch)	100% Conifers (spruce, pine & fir)	61%conifer 39% poplar
Ratio of logs stored to log yard area	8500	3530	6000	4875	18750
Soil Characteristics	Silty/clay till	Silty/clay till	clay	Muskeg / clay	Silty/sandy topsoil
Runoff Control Practices	All runoff captured in pond	Log yard runoff directed to ditch	Runoff directed to three culverts	No defined runoff path	No defined runoff path

Ratio of Logs Stored to Log Yard Area

One of the factors that could affect log yard runoff is the ratio of the number of logs stored at the site compared to the area of the log yard. It is expected that the higher the ratio of logs stored to log yard area, the higher the levels of organics and other substances found in logs, such as phenol would be in the runoff. To assess this factor a comparison of the M-W-M test results using this factor to compare the test sites can be made. The M-W-M test results did not indicate that this factor was significant. Other factors must therefore play a more important role for these two test sites than the ratio of logs stored to the storage area.

An assessment of the effect of the ratio of logs stored to log yard area can be made by comparing the runoff quality from Test Site #5, the highest ratio of 18,750 to Test Site #2 with a ratio of 3,530. The expectation would be that the higher the ratio, i.e., the greater the number of logs stored at the site compared to the area they are stored in, the more log yard leachate could be generated. The results of the M-W-M test indicate that for most parameters there was a significant difference between the sites. Test Site #2 with less logs stored than Test Site #5 had a higher concentration of the organics COD and phenol. Other factors must therefore play a more important role for these two test sites than the ratio of logs stored to the storage area.

Ratio of Logs Stored to Log Yard Area

The over view of the wood chemistry provided in Section 4 indicated that wood chemistry varied primarily between softwood and hardwoods. Tannins, lignins and resins acids are typically at higher levels in softwood barks than in hardwoods. It was noted in a study on aspen leachate that high levels of phenols were observed. The runoff from Test Sites #1and #2 containing aspen and pine respectively typically had the highest levels of organics. Test Site #5 containing a mixture of softwood and hardwood typically had low levels of organics and Test Site #4 containing spruce had the lowest levels. Based on the above information the difference in log yard runoff may be attributable to the tree species, i.e., runoff from aspen and pine log yards may have higher organic levels compared to runoff from spruce log yards. Test Site #4, however, was also unique from the other test sites in that it had a muskeg/clay surface. In addition, this site, like Test Site #5, did not have as defined a runoff path and had fewer samples collected from the site. The species of logs stored at the site may affect the log yard runoff but the importance of this factor in comparison to other factors cannot be determined with the data collected.

Soil Characteristics at Test Sites

The soil types at the five test sites can be divided into either predominantly clay, muskeg-clay and silty/sandy topsoil. One possible result of a clay soil is that the precipitation tends to run off rather than infiltrate, therefore there may be an opportunity for the runoff to pool for a longer time period. Comparison of the W-M-W test results for Test Site #1 (silty-clay) and Test Site #5 (gravel) indicate that there was no significant difference for pH and TSS between the two sites, however for COD and phenol there was a significant difference. Test Site #1 had higher levels of COD and phenols compared with Test Site #5. These results indicate that a clay surface may result in higher levels of organics in the runoff compared to a site with a silty / sandy soil. However, as discussed above, Test Site #5 did not have a well defined runoff path and in addition, fewer samples were taken from the site.

Management of Runoff at the Test Site

Comparison of Test Sites #1 and #5 and Test Site #2 and #4 can be used to analyze whether directing runoff to one location compared to no specific runoff management is a factor in the measured runoff quality at a site. Test Site #1, where all the runoff is directed to a retention pond, had higher levels of COD and phenols compared to Test Site #5 where the runoff infiltrated or discharged to the surrounding environment. At Test Site #2 runoff is also directed to one location compared to Test Site #4. Runoff control at Test Sites #4 and #5 were both passive. The results may indicate that a true sample of the runoff was not obtained because of limitations at the site or that the runoff either infiltrated or was released to the surrounding environment and did not have an opportunity to pool at the site resulting in less log yard leachate.

6.3 Effectiveness of a Retention Pond in Treating Log Yard Runoff

All the runoff generated at Test Site #1 was directed to a retention pond. AENV and AGAT Laboratories collected samples of the pond influent, the pond, and the pond effluent during June 1996, October 1996 and April 1997. The W-M-W test was performed to assess whether the pond influent water quality was significantly different compared to the pond effluent quality. Figure 11 provides plots of pH, COD and phenol concentrations of the pond influent and effluent. The W-M-W test indicated that there was a significant difference between the pond inlet and outlet quality for these three parameters. This improvement in the water quality is due to oxidation of the organic matter resulting in a removal efficiency for COD, TOC and phenols of approximately 60%. This removal efficiency is based on the median values.

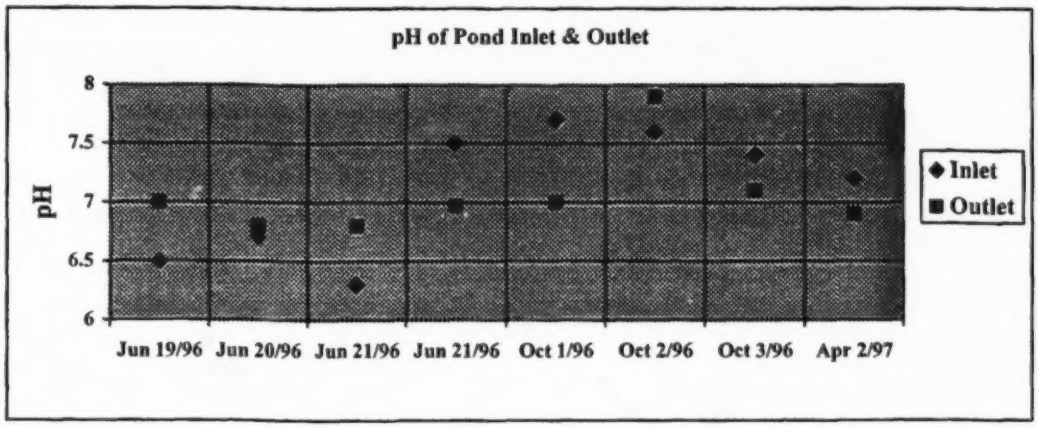


Figure 11 Plots of pH of Pond Inlet and Outlet

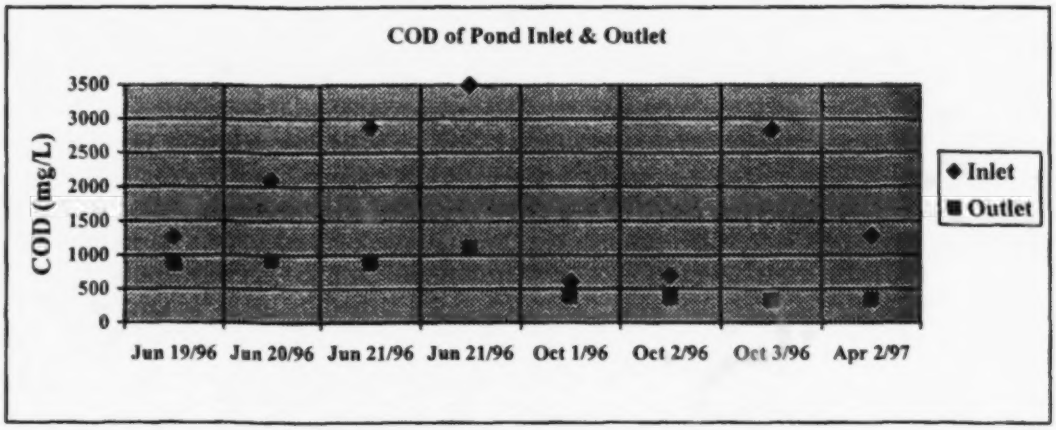


Figure 12 Plots of COD Pond Inlet and Outlet

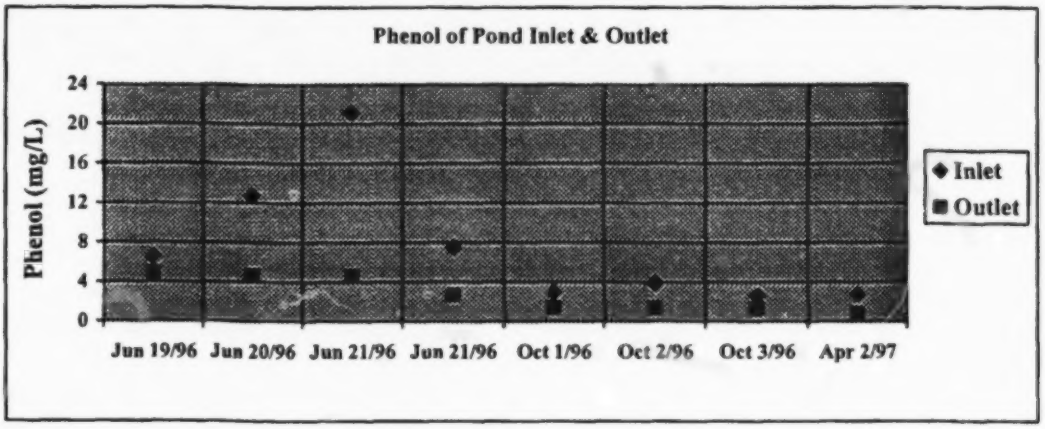


Figure 13 Plots of Phenol Pond Inlet and Outlet

The W-M-W test indicated that the TSS in the pond influent compared to the pond effluent was not significantly different. However, there was a greater range in TSS concentration in the pond influent (52 mg/L to 596 mg/L) compared to the pond effluent TSS (53 mg/L to 96 mg/L) for the eight samples taken. For three of the samples the pond influent TSS was high (264, 295 and 596 mg/L) but the pond effluent samples taken at the same time as the pond influent the TSS levels were much lower (63mg/L, 96 mg/L and 72 mg/L). These results would indicate that when the pond influent is carrying more TSS the TSS in the pond effluent is reduced by between 67 and 89%, respectively.

7.0 CONCLUSIONS

The major findings of this monitoring program are summarized below:

- Log yard runoff quality does exceed the background water quality. A comparison of the analytical results of 11 samples collected at three control sites to the three associated log yard sites indicated that the concentrations of organics such as COD, BOD, TOC and phenols in log yard runoff quality is higher than in runoff from an undisturbed forested area.

- Log yard runoff has variable toxicity. A comparison of the bioassay test results of the three control sites and the associated log yard runoff sites indicated that the log yard runoff can vary widely in toxicity to both Rainbow Trout and *daphnia magna*, from completely non-toxic at 100% concentrations to LC50's of relatively low concentrations. The control samples showed less variability, and lower toxicity although the number of samples was limited.

- Log yard runoff exceeded typical stormwater limits for COD and TSS. The pH of the log yard runoff was within the accepted stormwater limit range of 6.0 to 9.5.

- It was difficult to attribute conclusively log yard site characteristics to higher levels of organics and TSS in the runoff. A statistical analysis, however, indicated that the runoff from log yards with clay soils, storing pine or aspen logs and having a defined runoff path tended to have higher organic and TSS levels compared to a log yard storing only spruce on a muskeg/clay surface. More monitoring and analysis would be needed to confirm that specific tree species stored at a log yard site or the site soil characteristics resulted in a runoff that had substantially lower concentrations of contaminants.

- A retention pond collecting log yard runoff reduced the BOD, COD, phenols and TOC in the runoff entering the pond by 60%. This was based on the results of analysis of 16 samples consisting of eight samples of the pond influent and eight samples of the pond effluent.

- Based on the monitoring results and the data analysis done, runoff control measures are necessary at log yard sites located in sensitive areas, for example at sites where log yard runoff enters nearby receiving water body.

8.0 APPROACHES FOR MANAGING LOG YARD RUNOFF

The results of the monitoring program showed that regardless of the site characteristics, all log yards showed elevated levels of organics, TSS and nutrients. Some of the policies and guidelines followed by the United States Environmental Protection Agency, State of Washington Department of Ecology, B.C. Ministry of the Environment, the New Brunswick Department of Environment and the Ontario Ministry of Environment and Energy are provided in Alberta Environment's report *Assessment of Log Yard Runoff in Alberta Preliminary Evaluation,* June 1996. The general approach, in these locations, to managing runoff from log yards is to implement Best Management Practices (BMPs) that reflect the specifics of the log yard site and the sensitivity of the surrounding environment.

Washington State Department of Ecology published a report in May 1995, *Best Management Practices to Prevent Stormwater Pollution at Log Yards* outlining that industries with log yards must prepare Stormwater Pollution Prevention Plans (SWPP) that include BMPs that will be implemented. BMPs are categorized as Operational, Source Control, Erosion and Sediment Control, Treatment and Innovative BMPs. As a minimum, operational, source control and erosion and sediment control BMPs are required in SWPP. Examples of these BMPs from the Washington State Department of Ecology's published report are provided below.

Operational BMPs include:

- Formation of a Pollution Prevention Team,
- Practice good housekeeping measures such as frequent removal of debris, remove accumulated oil from oil/water separators, and
- Control weeds and other vegetation by considering the alternatives to the use of herbicide.

Examples of source control BMPs include:

- Locate storage areas on stable, well-drained soils, sloped to prevent run-on of uncontaminated stormwater,
- Stack materials to minimize surface areas of materials exposed to precipitation.

Examples of Erosion and Sediment Control BMPs include:

- Stabilize all soil areas which are eroding, or may potentially erode with appropriate erosion and sediment control BMPs.
- Install and maintain vegetative or paved drainage or otherwise stabilized swales or ditches, and/or sedimentation basin, as needed.

Treatment and Innovative BMPs are used when operational and source control BMPs do not reduce pollutants. This may be most applicable for sites that have poor runoff quality in terms of high levels of organics or TSS, and sites that are located in sensitive areas, for example at sites where log yard runoff enters a nearby receiving water body.

- Direct stormwater to a retention pond,
- Install aeration in the pond if the organic levels (BOD, COD, TOC) remain high.
- Install innovative treatment methods such as biofiltration (grassy swales, vegetative filter strips) or constructed wetlands for treatment of BOD, COD, TOC.

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APPENDIX A – SUGGESTIONS FOR DEVELOPING A SURFACE RUNOFF MANAGEMENT PLAN (SRMP)

Suggestions for Developing a Surface Runoff Management Plan (SRMP)

Development of a Surface Runoff Management Plan (SRMP) is a suggested approach to managing runoff from log yards so that impacts to the environment are minimized. Three components of a SRMP are listed below and described under Parts I to III.

- Characterization of the surface runoff drainage path, quality and quantity,
- A description of the surrounding environment, and
- A description of Best Management Practices/runoff control measures.

Part I Characterize the Surface Runoff Drainage Path, Quality and Quantity

As a first step, it is suggested that the surface runoff drainage path be determined and recorded. The benefit to sampling and chemical analysis of the runoff and estimating the quantity of the runoff is that more appropriate Best Management Practices can be determined. More detail is provided below as a guide for characterizing surface runoff.

Log Yard Surface Runoff Drainage Path

Determining the log yard surface runoff drainage path will assist in planning sampling locations for the surface runoff, calculating the runoff quantity, and determining appropriate Best Management Practices. To illustrate and maintain a record for further planning, a topographical map showing the plant site, log yard and the drainage path of surface runoff are suggested.

Log Yard Surface Runoff Chemistry

To characterize the log yard runoff quality, sampling of surface runoff during the spring runoff period, and storm events in the summer or fall for chemical analysis and bioassay testing is suggested. The following could be included in the description of the surface water quality:

- The following parameters are suggested for analysis of log yard runoff: pH, COD, BOD_5, ammonia-nitrogen, total phosphorous, TOC, TSS, TDS, oil and grease, total phenols, Resin and Fatty acids, tannins and lignins, and toxicity testing (e.g. Rainbow Trout lethality – 96 hours, Microtoxicity).
- Recorded information such as the sampling location and appearance of the log yard will assist in interpreting the data and help in consistency of further sampling and analysis.
- If possible, an estimate of the volume of storm water discharged during the sampling event that can then be used to calculate the specific parameter (i.e., BOD, TSS, etc) loading in the log yard runoff.

Groundwater Chemistry of Monitoring wells in a Log Yard

If sampling and analysis of groundwater in monitoring wells located in the log yard is available, the following is suggested to be included in the description of the groundwater quality:

- A brief description of the geology of the area should be provided;
- A review of groundwater data related to the log yard area and, if possible, the results of chemical analysis of parameters specifically related to log yard runoff including: pH, conductivity, turbidity, tannins and lignins, COD, TOC, TDS, and total phenols.

Log Yard Runoff Quantity

A method for determining the quantity of surface runoff from storm events is described in "A Guide to Content of Industrial Approval Applications Attachment B, Industrial Runoff Drainage System" (Alberta Environment, Industrial Program Development Branch, Environmental Sciences Division, September 1999). The following are suggested to be included in this part:

- An estimate of runoff infiltrating the ground, and
- Since log storage and surface runoff are typically expected to be at their maximum in the spring, an estimate of spring runoff also be calculated.

Part II Describe the Surrounding Environment

The purpose of describing the surrounding environment is to identify any potentially sensitive areas and provide information on the background water and vegetation quality. More details are provided below for guidance.

- An overview map showing the location of the site and the surrounding environment.
- A description of the surrounding environment including land use (industrial, farmland, residential, undeveloped, etc.) and land type (forest, swamp, wetland, grassland, etc.) and proximity to a receiving water.
- Inclusion of water quality data for receiving water bodies that is available, in other cases monitoring water bodies including wetlands, will assist in determining the impact of log yard runoff.
- Visual inspection of vegetation (indicator species) conducted during the summer.

Part III Provide Best Management Practices (BMP)

Best Management Practices (BMP) are practices that, once implemented, minimize impacts to the environment from log yard runoff. It is suggested that BMPs that are in place or proposed be identified in the SRMP. Proposed BMPs should include a date when they will be implemented. Some examples of BMPs are listed below. More detail is provided in regulatory documents (Alberta Environmental Protection, 1994), U.S. EPA (Smoley, 1993), and the State of Washington (Washington State Department of Ecology, 1995).

- Identify the person/people responsible for developing and implementing the SRMP, e.g., the plant or woodlands manager, environmental coordinator, log yard supervisor, safety coordinator.
- Train people who work in the log yard of their responsibilities outlined in the SRMP.
- Describe procedures to ensure that *good housekeeping* of the log yard is maintained, i.e., the log yard and ditches are free of waste material such as bark or wood chips that can be carried away by runoff, deposited into surface waters, or cause leachate formation. Details such as clean-up and inspections to be followed, and their frequency.
- Prevent leaks and spills of log yard equipment by following manufacturer's maintenance manual/instructions and conducting maintenance (replacing hydraulic oils, etc.) on an impervious surface.

- Avoid use of herbicides to control weeds, etc. and do not apply herbicides within close proximity of drainage ditch leading to open water or near open water including wetlands, ponds, lakes, rivers, etc.
- Minimize runoff from entering site and prevent ponding, erosion, and leachate formation by providing proper sloping and ditching which will reduce the contact time between wood material and runoff.

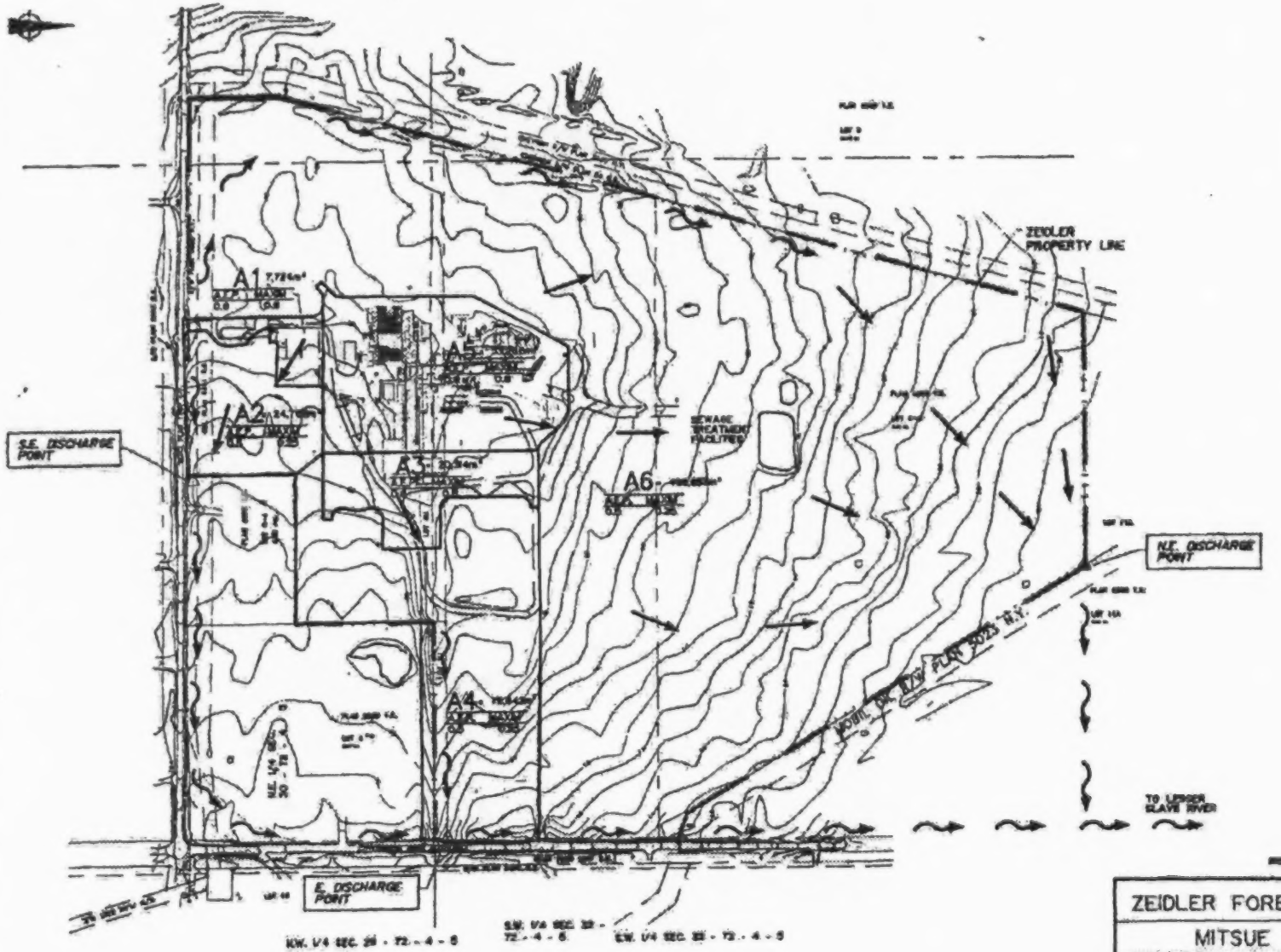
BMPs for controlling or minimizing erosion due to log yard runoff:

- Vegetative cover such as grass, trees or riprap, i.e., a permanent ground cover of large, loose, angular stone such as gravel.
- Installation of geotextiles to stabilize the top rock layer in areas of high activity and where erosion of the log yard occurs.
- Check dams or erosion berms, i.e., a small dam constructed from gravel across a drainage ditch or channel to lower the runoff velocity.

BMPs for controlling or minimizing possible contaminants due to log yard runoff:

- Retention ponds with either natural or induced aeration.
- Infiltration systems, e.g., ponds, trenches, porous pavement. To ensure that infiltration will NOT cause groundwater contamination, the suitability of infiltration must be evaluated based on the soils and geological conditions (e.g., low removal of pollutants in coarse soils), drainage area being treated is small enough, etc.
- Biofiltration systems such as grassy swales, vegetative filter strips, etc.

APPENDIX B – SITE PLANS



ZEIDLER FOREST INDUSTRIES L

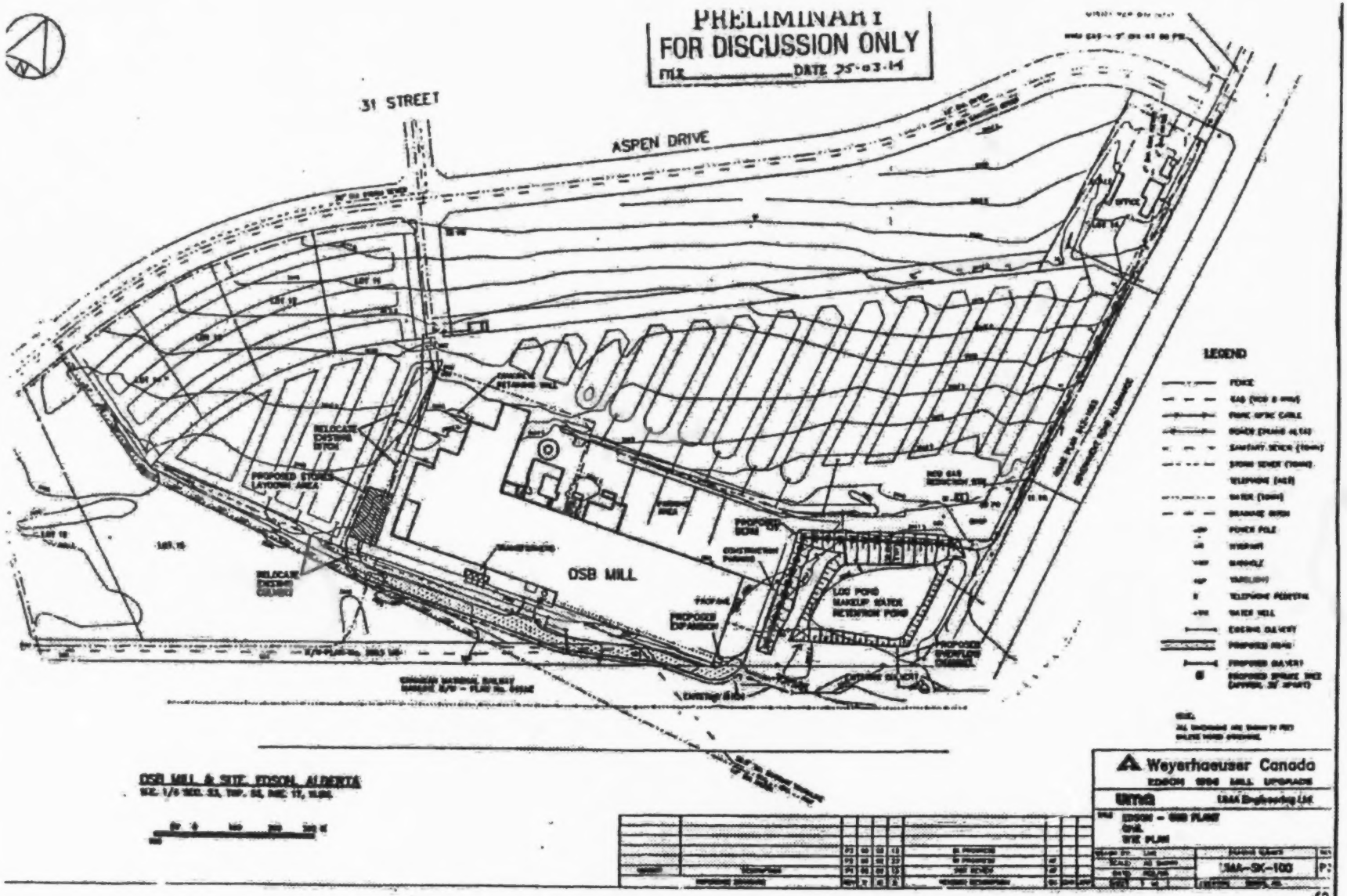
MITSUE VENEER PLANT

SITE TOPOGRAPHY & EXISTING DRAINAGE

MAXIM ENGINEERING INC.

N.T.S.

FIGURE 4


PRELIMINARY
FOR DISCUSSION ONLY
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LEGEND
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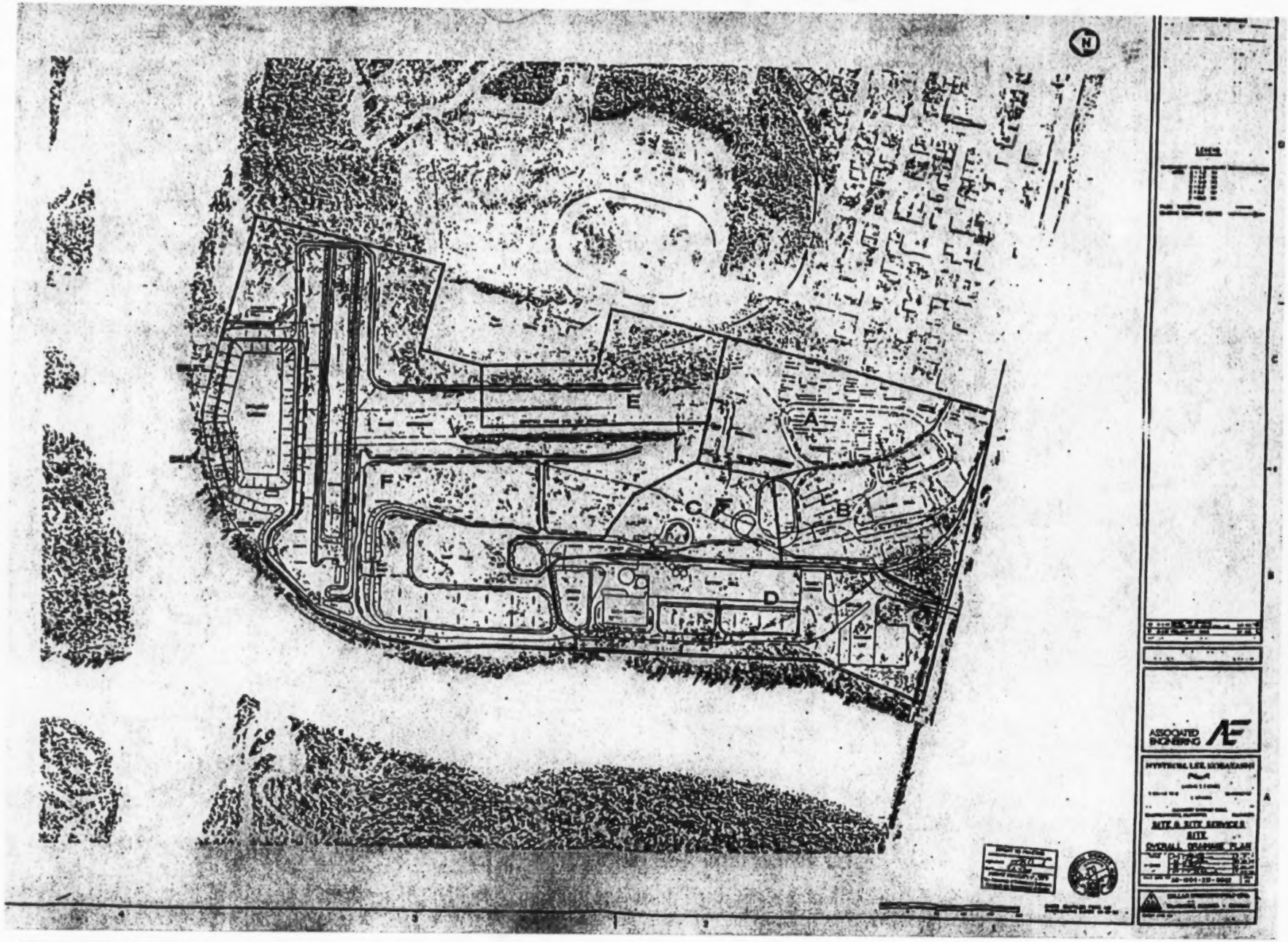
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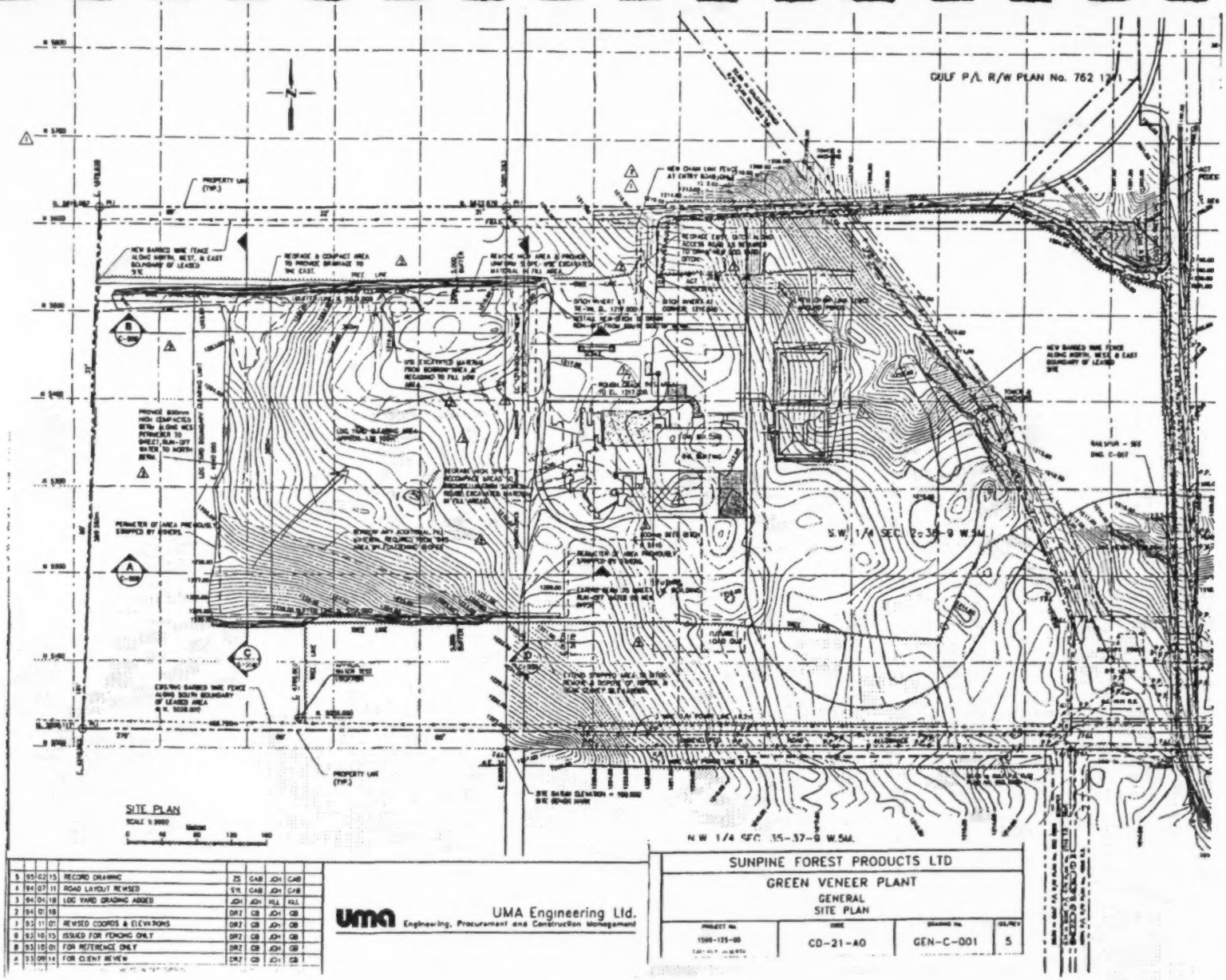
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SUNPINE FOREST PRODUCTS LTD
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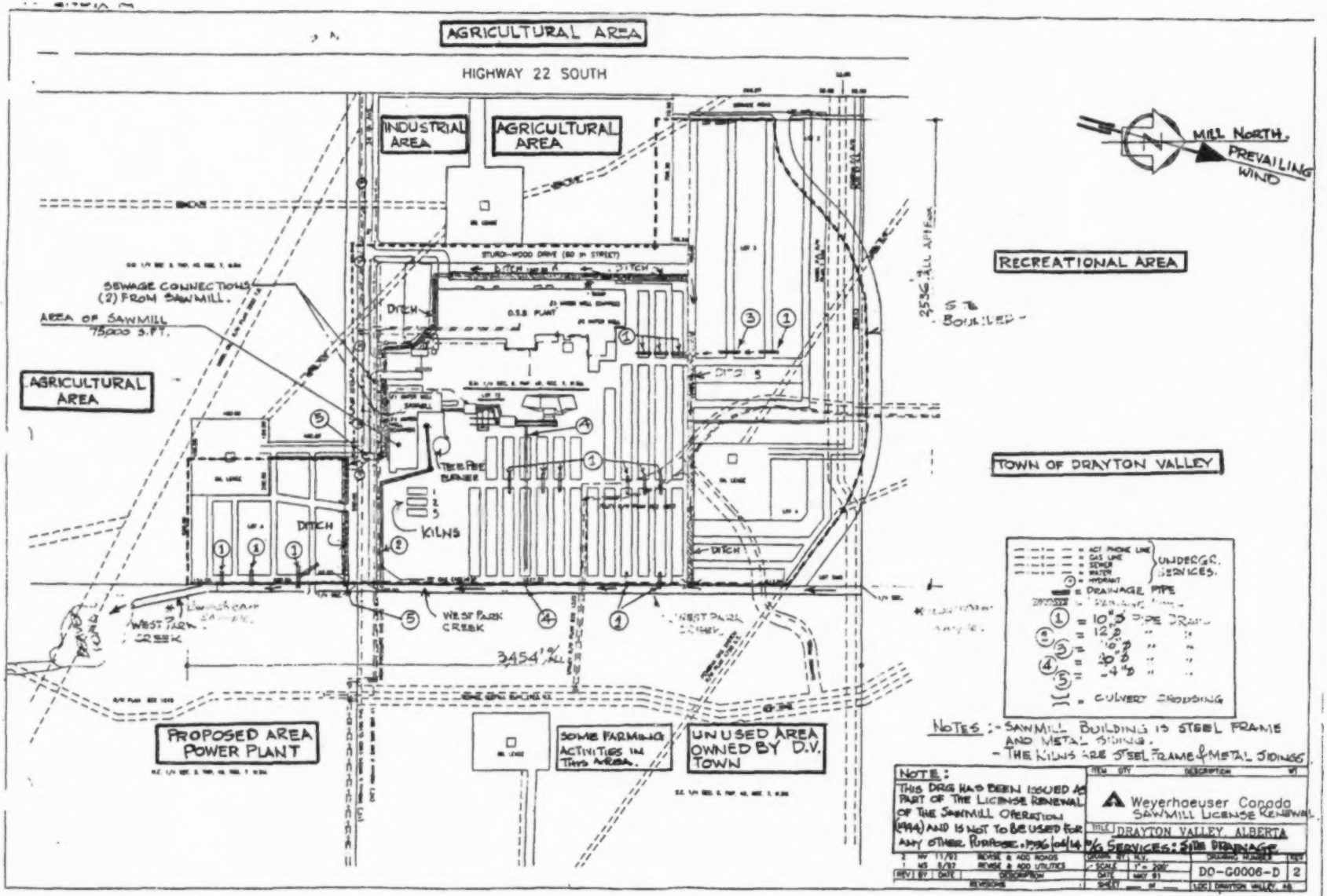
UMA Engineering Ltd.
Engineering, Procurement and Construction Management


AGRICULTURAL AREA
HIGHWAY 22 SOUTH
INDUSTRIAL AREA
AGRICULTURAL AREA
MILL NORTH.
PREVAILING WIND
RECREATIONAL AREA
SEWAGE CONNECTIONS (2) FROM SAWMILL.
AREA OF SAWMILL 75000 S.F.
AGRICULTURAL AREA
DITCH
KILNS
TOWN OF DRAYTON VALLEY
WEST PARK CREEK
3454'
PROPOSED AREA POWER PLANT
SOME FARMING ACTIVITIES IN THIS AREA.
UNUSED AREA OWNED BY D.V. TOWN
UNDERGR. SERVICES.
DRAINAGE PIPE
CULVERT CROSSING
NOTES :- SAWMILL BUILDING IS STEEL FRAME AND METAL SIDING.
- THE KILNS ARE STEEL FRAME & METAL SIDING.
NOTE: THIS DRG HAD BEEN ISSUED AS PART OF THE LICENSE RENEWAL OF THE SAWMILL OPERATION (1994) AND IS NOT TO BE USED FOR ANY OTHER PURPOSE.
Weyerhaeuser Canada
SAWMILL LICENSE RENEWAL
DRAYTON VALLEY, ALBERTA
SERVICES: SITE DRAINAGE
DO-G0006-D
DRAYTON VALLEY, AB

APPENDIX C - ANALYTICAL RESULTS FOR EACH TEST AND CONTROL SITE

Table C-1: Control Sites Chemical Analysis Results

Site / Location	Analysis	Date	pH	BOD (mg/L)	COD (mg/L)	TOC (mg/L)	Phenol (mg/L)	TSS (mg/L)	O & G (mg/L)	Ammonia - N (mg/L)	Tannin Lignin (mg/L)	Phosphate (mg/L)	Fatty Acids (ug/L)	Resin Acids (ug/L)
Control Site #1	AENV	Jun 21/96	7.57	1.9	52	17.8	<0.001	<0.4	0.3	0.22	1.3	0.014		
Control Site #1	AGAT	Jun 21/96	8.1	<2	45	22	0.01	19	<0.02	0.05	3.1			
Control Site #1	AGAT	Oct 3/96	8.4	<2	19	11	<0.002	<1.0	<0.20	<0.05	0.99			
Control Site #1	AENV	May 13/97	7.7	2	25	8	0.003	9	<1	<0.05	0.7		<10	<10
Control Site #2	Sunpine	Apr 17/96	7.53		18	10.7	0.014	13						
Control Site #2	Sunpine	Apr. 17/96	7.63		17	11.1	0.023	12						
Control Site #2	AENV	Apr. 17/96	7.88	0.9	<5	12.7	<0.001	3	<0.2	0.01	1.9			
Control Site #2	Sunpine	Apr. 9/98	7.6		53	17.8	0.003	1	20		2			
Control Site #2	AENV	Apr. 9/98	7.9	7.6	71	18.2	0.01	1	<2	<0.01	2.9		1.4	53.2
Control Site #3	AENV	Jun 19/96	7.29	2.2	63	23.2	<0.001	3	<0.2	0.02	1.4	0.083		
Control Site #3	AFPA	Spring/96	6.8	2.9	57		0.001	0.4	0.2		1.6			
Control Site #3	AENV	May 14/97	6.9	2	45	20	<0.001	7	<1	<0.05	1.3	0.05	<10	<10
Minimum			**6.8**	**0.9**	**<5**	**8**	**<0.001**	**<0.4**	**<0.02**	**<0.01**	**0.7**	**0.014**	**<10**	**<10**
Maximum			**8.4**	**7.6**	**71**	**23**	**0.023**	**19**	**20**	**0.22**	**3.1**	**0.083**	**1.4**	**53**
Average			**7.6**	**2.4**	**39**	**16**	**0.006**	**6**	**2.3**	**0.1**	**1.7**	**0.05**	**3.8**	**21**
Median			**7.6**	**2**	**45**	**18**	**0.002**	**3**	**0.3**	**0.03**	**1.5**	**0.05**	**5**	**5**
Count			**12**	**9**	**12**	**11**	**12**	**12**	**10**	**8**	**10**	**3**	**3**	**3**

Control Sites Bioassay Results

Site / Location	Analysis	Date	Trout Bioassay	Daphnia Magna		Microtox	pH	BOD (mg/L)	COD (mg/L)	TOC (mg/L)	Phenol (mg/L)
			LC50@96hrs	LC50 @48hrs	EC50 @48hrs						
Control Site #1	AENV	Jun 21/96		> 100%	> 100%	> 100%	7.57	1.9	52	17.8	<0.001
Control Site #1	AGAT	Jun 21/96	100%			> 90%	8.1	<2	45	22	0.01
Control Site #2	AENV	Apr. 17/97		> 100 %	> 100 %	> 100 %	7.88	0.9	<5	12.7	<0.001
Control Site #3	AENV	Jun 19/96		> 100 %	> 100 %	> 100 %	7.29	2.2	63	23.2	<0.001
Control Site #3	AFPA	Spring/96	> 100 %			> 100 %	6.8	2.9	57		0.001

Table C-2: Test Site #1 Chemical Analysis Results

Site / Location	Analysis	Date	pH	BOD (mg/L)	COD (mg/L)	TOC (mg/L)	Phenol (mg/L)	TSS (mg/L)	O & G (mg/L)	Ammonia -N (mg/L)	Tannin Lignin (mg/L)	Total Phosphorous (mg/L)	Fatty Acids (ug/L)	Resin Acids (ug/L)
Pond	AENV	Apr 16/96	7.22	147	300	72	0.23	33	2.1	0.1	27			
Pond Inlet	AGAT	Jun 19/96	6.5		1260	504	6.54	179		0.11				
Pond	AGAT	Jun 19/96	7		920	303	5.01	152						
Pond Inlet	AGAT	Jun 20/96	6.7	1000	2100	656	12.7	63	2.4	0.11	19.5			
Pond	AGAT	Jun 20/96	6.9	954	910	330	4.93	68	0.9	0.06	40.9			
Pond Outlet	AGAT	Jun 20/96	7	688	860	333	4.94	72	0.7	0.06	40.7			
Pond Inlet	AGAT	Jun 21/96	6.3		2880	1080	21.1	295						
Pond	AGAT	Jun 21/96	7		890	299	4.6	66						
Pond Outlet	AGAT	Jun 21/96	6.8		920	312	4.65	63						
Pond Outlet	AGAT	Jun 22/96	6.8		890	284	4.57	53						
Pond Inlet	AENV	Jun 21/96	7.5	1800	3500	1010	7.5	52	3.5	0.1	345	0.856		
Pond Outlet	AENV	Jun 21/96	6.97	330	1110	310	2.7	85	1.5	0.06	73	0.93	146.3	74
Pond Inlet	AGAT	Oct 1/96	7 7		610	190	2.98	61						
Pond	AGAT	Oct 1/96	7 1		360	113	1.31	92						
Pond Outlet	AGAT	Oct 1/96	7		390	123	1.43	60						
Pond Inlet	AGAT	Oct 2/96	7.6		690	213	3.85	74						
Pond	AGAT	Oct 2/96	7.7		380	117	1.39	110						
Pond Outlet	AGAT	Oct 2/96	7.9		370	116	1.35	60						
Pond Inlet	AGAT	Oct 3/96	7 4	156	2840	910	2.58	264	15.4	1.28	295			
Pond	AGAT	Oct 3/96	8	125	370	113	0.06	114	2.7		25.1			
Pond Outlet	AGAT	Oct 3/96	7.1	988	340	110	1.29	96	2.8	0.06	28.8			
Pond Inlet	AENV	Apr 2/97	7.2	873	1290	465	2.73	596	5	0.37	67.3	1.28	1218.1	52.9
Pond Outlet	AENV	Apr 2/97	6.9	205	347	148	0.791	72	2	0.23	28.9	0.52	161.5	60.4
	AFPA	Spring/97	6.8	192	510		1.1	56	<2		4.5		100	25
		Spring/97	7	308	520		1.1	73	<2		9.6			
		Spring/97	7	312	640		1.4	69	<2		3.8			
		Spring/97	6.9	279	570		1.4	62	<2		3.8			
	AFPA	Summer/97	7	444	780		2.70	76	3.00		72			
		Summer/97	7	412	720		2.70	68	4.80		77			
		Summer/97	7	417	830		3.20	80	3.40		79			
		Summer/97	7	440	840		15.00	45	2.80		75			
	AGAT	June 18/98	7.3	110	400	113	0.411	38	0.4	<0.05	21.7			
Minimum			**6.3**	**110**	**300**	**72**	**0.06**	**33**	**0.4**	**<0.05**	**4**	**0.52**	**100**	**25**
Maximum			**8**	**1800**	**3500**	**1080**	**21.1**	**596**	**15.4**	**1.28**	**345**	**1.28**	**1,218**	**74**
Average			**7.1**	**509**	**948**	**343**	**4.0**	**105**	**2.9**	**0.2**	**67**	**0.90**	**406**	**53**
Median			**7**	**371**	**750**	**292**	**2.7**	**71**	**2.3**	**0.1**	**35**	**0.89**	**154**	**57**
Count			**32**	**20**	**32**	**24**	**32**	**32**	**20**	**12**	**20**	**4**	**4**	**4**

Table C-3: Test Site #1 Bioassay Results

Site / Location	Analysis	Date	Trout Bioassay LC50@96hrs	Daphnia Magna Bioassay LC50@48hrs	Daphnia Magna Bioassay EC50@48hrs	Microtox	pH	BOD (mg/L)	COD (mg/L)	TOC (mg/L)	Phenol (mg/L)
Pond	AENV	Apr 16/96		> 100%	> 100%		7.22	147	300	72	0.23
Pond Inlet	AGAT	Jun 19/96					6.5		1260	504	6.54
Pond	AGAT	Jun 19/96					7		920	303	5.01
Pond Inlet	AGAT	Jun 20/96					6.7	1000	2100	656	12.7
Pond	AGAT	Jun 20/96					6.9	954	910	330	4.93
Pond Outlet	AGAT	Jun 20/96					7	688	860	333	4.94
Pond Inlet	AGAT	Jun 21/96					6.3		2880	1080	21.1
Pond	AGAT	Jun 21/96	21%				7		890	299	4.6
Pond Outlet	AGAT	Jun 21/96					6.8		920	312	4.65
Pond Outlet	AGAT	Jun 22/96					6.8		890	284	4.57
Pond Inlet	AENV	Jun 21/96		8.8%	8.8%	2.1%	7.5	1800	3500	1010	7.5
Pond Outlet	AENV	Jun 21/96		23%	23%	3.26%	6.97	330	1110	310	2.7
Pond Inlet	AGAT	Oct 1/96					7 7		610	190	2.98
Pond	AGAT	Oct 1/96					7.1		360	113	1.31
Pond Outlet	AGAT	Oct 1/96					7		390	123	1.43
Pond Inlet	AGAT	Oct 2/96					7.6		690	213	3.85
Pond	AGAT	Oct 2/96					7.7		380	117	1.39
Pond Outlet	AGAT	Oct 2/96					7.9		370	116	1.35
Pond Inlet	AGAT	Oct 3/96					7.4	156	2840	910	2.58
Pond	AGAT	Oct 3/96					8	125	370	113	0.06
Pond Outlet	AGAT	Oct 3/96					7 1	988	340	110	1.29
Pond Inlet		Apr 2/97					7.2	873	1290	465	2.73
Pond Outlet		Apr 2/97				7.60%	6.9	205	347	148	0.791
	AFPA	Spring/97	67%			10.60%	6.8	192	510		1.1
		Spring/97				13.5%	7	308	520		1.1
		Spring/97				12.7%	7	312	640		1.4
		Spring/97				10.3%	6.9	279	570		1.4
	AFPA	Summer/97	44%			2.30%	7	444	780		2.70
		Summer/97				1.86%	7	412	720		2.70
		Summer/97				1.84%	7	417	830		3.20
		Summer/97				2.03%	7	440	840		15.00
	AGAT	June 18/98	70%	not toxic			7.3	110	400	113	0.411
Minimum			**21%**	**9%**	**9%**	**1.8%**	**6.3**	**110**	**300**	**72**	**0.06**
Maximum			**70%**	**> 100%**	**> 100%**	**13.5%**	**8**	**1800**	**3500**	**1080**	**21.1**
Average			**51%**	**44%**	**44%**	**6.2%**	**7.1**	**509**	**948**	**343**	**4.0**
Median			**56%**	**23%**	**23%**	**3.3%**	**7**	**371**	**750**	**292**	**2.7**
Count			**4**	**3**	**3**	**11**	**32**	**20**	**32**	**24**	**32**

Table C-4: Test Site #2 Chemical Analysis Results

Analysis	Date	pH	BOD (mg/L)	COD (mg/L)	TOC (mg/L)	Phenol (mg/L)	TSS (mg/L)	O & G (mg/L)	Ammonia-N (mg/L)	Tannin Lignin (mg/L)	Total Phosphorous (mg/L)	Fatty Acids (ug/L)	Resin Acids (ug/L)
Sunpine	Mar 14/96	6.17		806	244	2.92	740	19 7	<0.005				
Sunpine	Mar 15/96	6.25		1480	426	4.53	312						
Sunpine	Mar 18/96	6.51		1200	390	3.93	248						
Sunpine	Apr 9/96	6.81		1940	453	3.9	266						
Sunpine	Apr. 16/96	6.31		2860		6.22	1150						
AENV	Apr. 16/96	7.07	983	600	830	0.104	455	29 7	0.12	165			
Sunpine	Apr.29/97	6.41		2020	455	0.9	173						
AENV	Apr.29/97	6.89	428	1860	570	0.27	143	13	0.23	145		363	2194.7
Sunpine	Apr. 9/98	7.4		1770	584	0.287	211	9		50.5			
AENV	Apr. 9/98	7.36	651	1660	516	0.33	42	22	0.06	65	0.377	115 1	2184.6
Minimum		**6.2**	**428**	**600**	**244**	**0.1**	**42**	**9**	**<0.005**	**51**		**115**	**2185**
Maximum		**7.4**	**983**	**2860**	**830**	**6.2**	**1150**	**30**	**0.23**	**165**		**363**	**2195**
Average		**6.7**	**687**	**1620**	**496**	**2.3**	**374**	**19**	**0.10**	**106**			
Median		**6.7**	**651**	**1715**	**455**	**1.9**	**257**	**20**	**0.09**	**105**			
Count		**10.0**	**3**	**10**	**9**	**10**	**10**	**5**	**4**	**4**	**1**	**2**	**2**

Table C-4: Test Site #2 Bioassay Results

Analysis	Date	Trout Bioassay	Daphnia Magna		Microtox	pH	BOD (mg/L)	COD (mg/L)	TOC (mg/L)	Phenol (mg/L)
		LC50@96hrs	LC50 @48hrs	EC50 @48hrs						
AENV	Apr. 16/96	26%	20%		7.80%	7.07	983	600	830	0.104
AENV	Apr. 17/96		55%	43%	9%	6.89	428	1860	570	0.27
AENV	Apr. 9/98				13.40%	7.36	651	1660	516	0.33

Table C-5: Test Site #3 Chemical Analysis Results

Site / Location	Analysis	Date	pH	BOD (mg/L)	COD (mg/L)	TOC (mg/L)	Phenol (mg/L)	TSS (mg/L)	O & G (mg/L)	Ammonia-N (mg/L)	Tannin Lignin (mg/L)	Total Phosphorous (mg/L)	Fatty Acids (ug/L)	Resin Acids (ug/L)
Conifer site	AENV	Apr 16/96	7.39	138	260	134	0.047	145	9.5	0.06	31.7			
Aspen	AENV	Jun 19/96	7.29	77	505	126	<0.001	0.4	5.5	0.17	11.4	1.01		
Conifer site	AENV	Jun 19/96	7.93	52	490	129	0.018	0.4	5.5	0.09	12.2	0.779		
Aspen Site	AENV	Sept 6/96	7.68	84	450	165	0.1	28	2	0.06	11.6	0.231	0	10.5
Conifer	AFPA	Spring/96	7.7	82	470		0.01	636	3.7		12.7		318.7	960
Aspen/Conifer	AFPA	Spring/96	7.1	105	500		0.1	1420	2.5		28		487.5	660.7
Conifer	AFPA	Fall /96	7.9	36	500		0.014		0.7		10.5			
Conifer	AFPA	Fall /96	8		430		0.093							
Conifer	AFPA	Fall /96	8.2		420		0.001							
Aspen/Conifer	AFPA	Fall /96	7.6	69	500		0.96		2		28		79	520
Aspen/Conifer	AFPA	Fall /96	7.8		450		0.056							
Aspen/Conifer	AFPA	Fall /96	7.7		410		0.196							
Culvert 2	AENV	Mar 26/97	9.1	1330	3030	945	1.03	960	25	0.11	142	3.01	713	15265
Conifer site	AENV	Mar 26/97	7.6	177	621	174	0.037	160	11	0.3	19.7	1.03	117.9	4341
Conifer	AFPA	Spring/97	6.6	157	530		0.042	275	4.1		34		470	3800
	AFPA	Spring/97	6.5	192	580		0.046	52	6		50			
	AFPA	Spring/97	6.9	287	800		0.058	94	5.8		59			
	AFPA	Spring/97	6.6	245	750		0.044	132	5.8		58			
Aspen/Conifer	AFPA	Spring/97	7	945	2550		1.3	280	8		178		570	9300
	AFPA	Spring/97												
	AFPA	Spring/97	6.6	1125	2250		1.6	224	10		165			
	AFPA	Spring/97	6.4	840	1800		1.5	56	9.1		130			
Conifer	AFPA	Summer/97	7.5	111	740		0.089	1485			20		120	560
	AFPA	Summer/97	7.5	105	750		0.056	1250			19			
	AFPA	Summer/97	7.6	134	600		29	304			17			
	AFPA	Summer/97	7.9	137	690		1.9	22			25			
Aspen/Conifer	AFPA	Summer/97	7.1	291	1190		0.90	475			58		79	230
	AFPA	Summer/97	7.2	275	1440		1	3015			55			
	AFPA	Summer/97	7.3	281	910		2.6	110			59.2			
	AFPA	Summer/97	7.4	534	1200		9.8	24			61.6			
Culvert 3	AENV	May 14/97	7.5	304	718	284	0.09	568	22	<0.05	32.6	1.33	196.2	3400
Minimum			**6.4**	**36**	**260**	**126**	**<0.001**	**0**	**1**	**<0.05**	**11**	**0.23**	**0**	**11**
Maximum			**9.1**	**1330**	**3030**	**945**	**29**	**3015**	**25**	**0.3**	**178**	**3.01**	**713**	**15265**
Average			**7.4**	**312**	**884**	**280**	**1.7**	**488**	**8**	**0.1**	**51**	**1.23**	**286**	**3550**
Median			**7.5**	**167**	**611**	**165**	**0.1**	**192**	**6**	**0.1**	**32**	**1.02**	**196**	**960**
Count			**30**	**26**	**30**	**7**	**30**	**24**	**18**	**7**	**26**	**6**	**11**	**11**

Table C-6: Test Site #3 Bioassay Results

Site / Location	Analysis	Date	Trout Bioassay LC50@96hrs	Daphnia Magna Bioassay		Microtox	pH	BOD (mg/L)	COD (mg/L)	TOC (mg/L)	Phenol (mg/L)
				LC50 at 48hrs	EC50 at 48hrs						
Conifer site	AENV	Apr 16/96		> 100 %	> 100 %	58.2%	7.39	138	260	134	0.047
Aspen	AENV	Jun 19/96		> 100 %	> 100 %	87.6%	7.29	77	505	126	<0.001
Conifer site	AENV	Jun 19/96		> 100 %	> 100 %	> 100	7.93	52	490	129	0.018
Aspen Site	AENV	Sept 6/96		> 100 %	> 100 %	> 100	7.68	84	450	165	0.1
Conifer	AFPA	Spring/96	90%			76%	7.7	82	470		0.01
Aspen	AFPA	Spring/96	95%			39%	7 1	105	500		0.1
Conifer	AFPA	Fall /96	> 100			> 100	7.9	36	500		
Culvert 2	AFPA	Mar 26/97		30%		46.0%	9.1	1330	3030	945	1.03
Conifer site	AFPA	Mar 26/97		> 100 %		5.9%	7.6	177	621	174	0.037
Conifer	AFPA	Spring/97	32%			60.6%	6.6	157	530		0.042
	AFPA	Spring/97				19.3%	6.5	192	580		0.046
	AFPA	Spring/97				22.3%	6.9	287	800		0.058
	AFPA	Spring/97				25.4%	6.6	245	750		0.044
Aspen/Conifer	AFPA	Spring/97	7%			11.5%	7	945	2550		1.3
	AFPA	Spring/97									
	AFPA	Spring/97				2.4%	6.6	1125	2250		1.6
	AFPA	Spring/97				1.5%	6.4	840	1800		1.5
Conifer	AFPA	Summer/97	47%			91.2%	7.5	111	740		0.089
	AFPA	Summer/97				84.1%	7.5	105	750		0.056
	AFPA	Summer/97				>100	7.6	134	600		29
	AFPA	Summer/97				44.7%	7.9	137	690		1.9
Aspen/Conifer	AFPA	Summer/97	14%			14.7%	7.1	291	1190		0.90
	AFPA	Summer/97				16.6%	7.2	275	1440		1
	AFPA	Summer/97				20.2%	7.3	281	910		2.6
	AFPA	Summer/97				4.9%	7 4	534	1200		9.8
Minimum			**7%**	**30%**	**>100%**	**1%**	**6.4**	**36**	**260**	**126**	**<0.001**
Maximum			**>100%**	**100%**	**>100%**	**100%**	**9.1**	**1330**	**3030**	**945**	**29**
Average			**55%**	**88%**	**>100%**	**47%**	**7.3**	**323**	**984**	**279**	**2.3**
Median			**47%**	**100%**	**>100%**	**42%**	**7.3**	**157**	**690**	**150**	**0.1**
Count			**7**	**6**	**4**	**24**	**24**	**24**	**24**	**6**	**22**

Table C-7: Test Site #4 Chemical Analysis Results

Site / Location	Analysis	Date	pH	BOD (mg/L)	COD (mg/L)	TOC (mg/L)	Phenol (mg/L)	TSS (mg/L)	O & G (mg/L)	Ammonia-N (mg/L)	Tannin Lignin (mg/L)	Total Phosphorous (mg/L)	Fatty Acids (ug/L)	Resin Acids (ug/L)
Site 1	AENV	Apr. 17/97	7.3	57	165	62	0.005	8	1	0.09	4.5	0.15	8.1	324.1
Site 2	AENV	Apr. 17/97	7 4	104	281	87	0.007	13	2	0.29	8.4	0.3	17	315.3
Conifer	AFPA	Spring /97	6.9	26	195		0.003	<0.4	<2					
		day 2	7.3	56	270		0.11	4	<2					
		day3	7.2	24	160		0.001	2	<2					
		day4	7.2	23	175		<0.001	3	<2					
Conifer	AFPA	Summer /97	7.5	45	290		0.017	1	2.2					
		day 2	7.6	43	260		0.025	2	<2					
		day 3	7.5	40	220		0.07	2	<2					
		day 4	7.5	34	270		0.03	<0.4	<2					
Conifer	AFPA	Fall /97	7	36	350		0.24	10	<2					
Site 1	AENV	June 19/97	7.6	63	278	77	0.018	12	4	<0.05	8.3	0.19	59.6	474.1
Site 2			7.5	57	328	114	0.006	11	3	<0.05	7.1	0.17	32.6	173.8
Minimum			**6.9**	**23**	**160**	**62**	**<0.001**	**<0.4**	**1**	**<0.05**	**4.5**	**0.15**	**8.1**	**173.8**
Maximum			**7.6**	**104**	**350**	**114**	**0.24**	**13**	**4**	**0.29**	**8.4**	**0.3**	**59.6**	**474.1**
Average			**7.3**	**47**	**249**	**85**	**0.04**	**5**	**2**	**0.11**	**7.1**	**0.2**	**29.3**	**321.8**
Median			**7.4**	**43**	**270**	**82**	**0.02**	**3**	**1**	**0.06**	**7.7**	**0.2**	**24.8**	**319.7**
Count			**13**	**13**	**13**	**4**	**13**	**13**	**13**	**4**	**4**	**4**	**4**	**4**

Table C-7: Test Site #4 Bioassay Results

Site / Locatio	Analysis	Date	Trout Bioassay	Daphnia Magna Bioassay		Microtox	pH	BOD (mg/L)	COD (mg/L)	TOC (mg/L)	Phenol (mg/L)
			LC50@96hrs	LC50@	EC50@						
Site 1	AENV	Apr. 17/97		>100	>100	53%	7.3	57	165	62	0.005
Site 2	AENV	Apr. 17/97		>100	>100	94.3%	7 4	104	281	87	0.007
Conifer	AFPA	Spring /97	100%			>100%	6.9	26	195		0.003
		day 2				82.4%	7.3	56	270		0.11
		day3				>100%	7.2	24	160		0.001
		day4				>100%	7.2	23	175		<0.001
Conifer	AFPA	Summer /97	100%			>100%	7.5	45	290		0.017
		day 2				>100%	7.6	43	260		0.025
		day 3				>100%	7.5	40	220		0.07
		day 4				>100%	7.5	34	270		0.03
Conifer	AFPA	Fall /97	>100%			>100%	7	36	350		0.24
Site 1	AENV	June 16/97		>100	>100		7.6	63	278	77	0.018
Site 2	AENV	June 16/97		>100	>100		7.5	57	328	114	0.006
Minimum			**100%**	**>100**	**>100**	**53%**	**6.9**	**23**	**160**	**62**	**<0.001**
Maximum			**100%**	**>100**	**>100**	**100%**	**7.6**	**104**	**350**	**114**	**0.24**
Average			**100%**	**>100**	**>100**	**94%**	**7.3**	**47**	**249**	**85**	**0.04**
Median			**100%**	**>100**	**>100**	**100%**	**7.4**	**43**	**270**	**82**	**0.02**
Count			**3**	**4**	**4**	**11**	**13.0**	**13**	**13**	**4**	**13**

Table C-8: Test Site #5 Chemical Analysis Results

Site / Location	Analysis	Date	pH	BOD (mg/L)	COD (mg/L)	TOC (mg/L)	Phenol (mg/L)	TSS (mg/L)	O & G (mg/L)	Ammonia-N (mg/L)	Tannin Lignin (mg/L)	Total P Phosphorous (mg/L)	Fatty acids (ug/L)	Resin acids (ug/L)
Site 1 Conifer	AENV	Apr. 23/97	7.6	176	608	201	0.028	116	<1	< 0.05	15.5	0.54	148.7	1064.5
Site 2 Aspen	AENV		7.9	84	540	136	0.047	512	3	<0.05	12.8	2.61	92.9	795.5
Conifer	AFPA	Spring /97	7.3	139	550		0.032	180	3.9					
		day 2	7.3	180	810		0.052	62	5.4					
		day 3	7 4	114	700		0.057	124	4.2					
		day 4	7.5	258	1280		0.047	755	6					
Aspen	AFPA	Spring /97	7.5	54	400		0.047	900	3.4					
		day 2	7 4	60	390		0.069	150	< 2					
		day 3	7.5	63	400		0.067	248	< 2					
		day 4	7.6	63	380		0.068	144	< 2					
Minimum			**7.3**	**54**	**380**	**136**	**0.028**	**62**	**<1**	**< 0.05**	**12.8**	**0.54**	**92.9**	**795.5**
Maximum			**7.9**	**258**	**1280**	**201**	**0.069**	**900**	**6**	**< 0.05**	**15.5**	**2.61**	**148.7**	**1064.5**
Average			**7.5**	**119**	**606**		**0.051**	**319**	**3**					
Median			**7.5**	**99**	**545**		**0.050**	**165**	**3**					
Count			**10**	**10**	**10**	**2**	**10**	**10**	**10**	**2**	**2**	**2**	**2**	**2**

Table C-8: Test Site #5 Bioassay Results

Site / Location	Analysis	Date	Trout Bioassay LC50@96hrs	Daphnia Magna Bioassay LC50@48 hrs	Microtox	pH	BOD (mg/L)	COD (mg/L)	TOC (mg/L)	Phenol (mg/L)
Site 1	AEP	Apr. 23/97		>100	34.8%	7.6	176	608	201	0.028
Site 2	AEP	Apr. 23/97		>100	92.2%	7.9	84	540	136	0.047
Conifer	AFPA	Spring /97	71%		61.9%	7.3	139	550		0.032
		day 2			35.4%	7.3	180	810		0.052
		day 3			74.9%	7 4	114	700		0.057
		day 4			58.1%	7.5	258	1280		0.047
Aspen	AFPA	Spring /97	100%		73.2%	7.5	54	400		0.047
		day 2			94.8%	7 4	60	390		0.069
		day 3			80.7%	7.5	63	400		0.067
		day 4			82.3%	7.6	63	380		0.068
Minimum			**71%**	**>100**	**34.8%**	**7.3**	**54**	**380**	**136**	**0.028**
Maximum			**100%**	**>100**	**94.8%**	**7.9**	**258**	**1280**	**201**	**0.069**
Average					**68.8%**	**7.5**	**119**	**606**		**0.051**
Median					**74.1%**	**7.5**	**99**	**545**		**0.050**
Count			**2**	**2**	**10**	**10**	**10**	**10**	**2**	**10**

Table C-9 Control Sites and Test Sites Chemical Analysis Results

Site / Location	Analysis	Date	pH	BOD (mg/L)	COD (mg/L)	TOC (mg/L)	Phenol (mg/L)	TSS (mg/L)	O & G (mg/L)	Ammonia - N (mg/L)	Tannin Lignin (mg/L)	Phosphate (mg/L)	Fatty Acids (ug/L)	Resin Acids (ug/L)
Control Site #1	AENV	Jun 21/96	7.57	1.9	52	17.8	<0.001	<0.4	0.3	0.22	1.3	0.014		
Control Site #1	AGAT	Jun 21/96	8.1	<2	45	22	0.01	19	<0.02	0.05	3.1			
Control Site #1	AGAT	Oct 3/96	8.4	<2	19	11	<0.002	<1.0	<0.20	<0.05	0.99			
Control Site #1	AENV	May 13/97	7 7	2	25	8	0.003	9	<1	<0.05	0.7		<10	<10
Control Site #2	Sunpine	Apr 17/96	7.53		18	10.7	0.014	13						
Control Site #2	Sunpine	Apr. 17/96	7.63		17	11.1	0.023	12						
Control Site #2	AENV	Apr. 17/96	7.88	0.9	<5	12.7	<0.001	3	<0.2	0.01	1.9			
Control Site #2	Sunpine	Apr. 9/98	7.6		53	17.8	0.003	1	20		2			
Control Site #2	AENV	Apr. 9/98	7.9	7.6	71	18.2	0.01	1	<2	<0.01	2.9		1.4	53.2
Control Site #3	AENV	Jun 19/96	7.29	2.2	63	23.2	<0.001	3	<0.2	0.02	1.4	0.083		
Control Site #3	AFPA	Spring/96	6.8	2.9	57		0.001	0.4	0.2		1.6			
Control Site #3	AENV	May 14/97	6.9	2	45	20	<0.001	7	<1	<0.05	1.3	0.05	<10	<10
Minimum			**6.8**	**0.9**	**<5**	**8**	**<0.001**	**<0.4**	**<0.02**	**<0.01**	**0.7**	**0.01**	**1.4**	**<10**
Maximum			**8.4**	**7.6**	**71**	**23**	**0.023**	**19**	**20**	**0.22**	**3.1**	**0.08**	**5.0**	**53**
Average				**2.4**	**39.0**	**16**	**0.006**	**6**	**2**	**0.1**	**1.7**	**0.05**	**3.8**	**21**
Median			**7.6**	**2**	**45**	**18**	**0.002**	**3**	**0.3**	**0.03**	**1.5**	**0.05**	**5.0**	**5**
Count			**12**	**9**	**12**	**11**	**12**	**12**	**10**	**8**	**10**	**3**	**3**	**3**
Test Site #1	AGAT	Jun 21/96	6.8		920	312	4.65	63						
Test Site #1	AEP	Jun 21/96	6.97	330	1110	310	2.7	85	1.5	0.06	73	0.93	146.3	74
Test Site #1	AEP	Apr 2/97	6.9	205	347	148	0.791	72	2	0.23	28.9	0.52	161.5	60.4
Test Site #2	Sunpine	Apr 9/96	6.81		1940	453	3.9	266						
Test Site #2	Sunpine	Apr. 16/96	6.31		2860	na	6.22	1150						
Test Site #2	AEP	Apr. 16/96	7.07	983	600	830	0.104	455	29 7	0.12	165			
Test Site #2	Sunpine	Apr. 9/98	7 4		1770	584	0.287	211	9		50.5			
Test Site #2	AEP	Apr. 9/98	7.36	651	1660	516	0.33	42	22	0.06	65	0.377	115.1	2184.6
Test Site #3	AFPA	Spring/96	7 7	82	470		0.01	636	3.7		12.7		318.7	960
Test Site #3	AFPA	Spring/96	7 1	105	500		0.1	1420	2.5		28		487.5	660.7
Test Site #3	AEP	Jun 19/96	7.29	77	505	126	<0.001	0.4	5.5	0.17	11.4	1.01		
Minimum			**6.3**	**77**	**347**	**126**	**<0.001**	**0.4**	**2**	**0.06**	**11**	**0.38**	**115.1**	**60**
Maximum			**7.7**	**983**	**2860**	**830**	**6.2**	**1420**	**30**	**0.23**	**165**	**1.01**	**487.5**	**2185**
Average				**347.57**	**1152.909**	**410**	**1.7**	**400.036**	**9**	**0.11**	**54**	**0.71**	**245.8**	**788**
Median			**7.1**	**205**	**920**	**383**	**0.3**	**211**	**5**	**0.09**	**40**	**0.73**	**161.5**	**661**
count			**11**	**7**	**11**	**8**	**11**	**11**	**8**	**6**	**8**	**4**	**5**	**5**

Table C-10: Test Site #1 Pond Inlet & Outlet Chemical Analysis Results

Site / Location	Analysis	Date	pH	BOD (mg/L)	COD (mg/L)	TOC (mg/L)	Phenol (mg/L)	TSS (mg/L)	O & G (mg/L)	Ammonia - N (mg/L)	Tannin Lignin (mg/L)	Total Phosphorous (mg/L)	Fatty Acids (ug/L)	Resin Acids (ug/L)
Pond Inlet	AGAT	Jun 19/96	6.5		1260	504	6.54	179		0.11				
Pond Inlet	AGAT	Jun 20/96	6.7	1000	2100	656	12.7	63	2.4	0.11	19.5			
Pond Inlet	AGAT	Jun 21/96	6.3		2880	1080	21.1	295						
Pond Inlet	AENV	Jun 21/96	7.5	1800	3500	1010	7.5	52	3.5	0.1	345	0.856		
Pond Inlet	AGAT	Oct 1/96	7.7		610	190	2.98	61						
Pond Inlet	AGAT	Oct 2/96	7.6		690	213	3.85	74						
Pond Inlet	AGAT	Oct 3/96	7.4	156	2840	910	2.58	264	15 4	1.28	295			
Pond Inlet	AENV	Apr 2/97	7.2	873	1290	465	2.73	596	5	0.37	67.3	1.28	1218.1	52.9
Minimum			**6.3**	**156**	**610**	**190**	**2.6**	**52**	**1**	**<0.05**	**19.5**	**0.856**	**1218.1**	**52.9**
Maximum			**7.7**	**1800**	**3500**	**1080**	**21.1**	**596**	**15.4**	**1.28**	**345**	**1.28**	**1218.1**	**52.9**
Average			**7.1**	**957**	**1896**	**629**	**7.5**	**198**	**3.8**	**0.3**	**181.7**			
Median			**7.3**	**937**	**1695**	**580**	**5.2**	**127**	**1.7**	**0.11**	**181.15**			
Count			**8**	**4**	**8**	**8**	**8**	**8**	**8**	**6**	**4**	**2**	**1**	**1**
Pond Outlet	AGAT	Jun 20/96	7	688	860	333	4.94	72	0.7	0.06	40.7			
Pond Outlet	AGAT	Jun 21/96	6.8		920	312	4.65	63						
Pond Outlet	AGAT	Jun 22/96	6.8		890	284	4.57	53						
Pond Outlet	AENV	Jun 21/96	6.97	330	1110	310	2.7	85	1.5	0.06	73	0.93	146.3	74
Pond Outlet	AGAT	Oct 1/96	7		390	123	1.43	60						
Pond Outlet	AGAT	Oct 2/96	7.9		370	116	1.35	60						
Pond Outlet	AGAT	Oct 3/96	7 1	988	340	110	1.29	96	2.8	0.06	28.8			
Pond Outlet	AENV	Apr 2/97	6.9	205	347	148	0.791	72	2	0.23	28.9	0.52	161.5	60.4
Minimum			**6.8**	**205**	**340**	**110**	**0.8**	**53**	**0.7**	**0.06**	**28.8**	**0.52**	**146**	**60**
Maximum			**7.9**	**988**	**1110**	**333**	**4.9**	**96**	**2.8**	**0.23**	**73**	**0.93**	**162**	**74**
Average			**7.1**	**553**	**653**	**217**	**3**	**70**	**1.8**	**0.1**	**42.9**			
Median			**6.985**	**509**	**625**	**216**	**2**	**68**	**1.75**	**0.06**	**34.8**			
Count			**8**	**4**	**8**	**8**	**8**	**8**	**4**	**4**	**4**	**2**	**2**	**2**

Table C-11 Test Site #3 - Aspen/Conifer & Conifer Log Yard Chemical Analysis Results

	Site / Location	Analysis	Date	pH	BOD (mg/L)	COD (mg/L)	TOC (mg/L)	Phenol (mg/L)	TSS (mg/L)	O & G (mg/L)	Ammonia - N (mg/L)	Tannin Lignin (mg/L)	Total Phosphorous (mg/L)	Fatty Acids (ug/L)	Resin Acids (ug/L)
1	Conifer site	AEP	Apr 16/96	7.39	138	260	134	0.047	145	9.5	0.06	31.7			
2	Conifer site	AEP	Jun 19/96	7.93	52	490	129	0.018	0.4	5.5	0.09	12.2	0.779		
3	Conifer	AFPA	Spring/96	7 7	82	470		0.01	636	3.7		12.7		318.7	960
4	Conifer	AFPA	Fall /96	7.9	36	500		0.014		0.7		10.5			
5	Conifer		Fall /96	8		430		0.093							
6	Conifer		Fall /96	8.2		420		0.001							
7	Conifer site	AEP	Mar 26/97	7.6	177	621	174	0.037	160	11	0.3	19 7	1.03	117.9	4341
8	Conifer	AFPA	Spring/97	6.6	157	530		0.042	275	4.1		34		470	3800
9	Conifer	AFPA	Spring/97	6.5	192	580		0.046	52	6		50			
10	Conifer	AFPA	Spring/97	6.9	287	800		0.058	94	5.8		59			
11	Conifer	AFPA	Spring/97	6.6	245	750		0.044	132	5.8		58			
12	Conifer	AFPA	Summer/97	7.5	111	740		0.089	1485	na		20		120	560
13	Conifer	AFPA	Summer/97	7.5	105	750		0.056	1250	na		19			
14	Conifer	AFPA	Summer/97	7.6	134	600		29	304	na		17			
15	Conifer	AFPA	Summer/97	7.9	137	690		1.9	22	na		25			
16	Conifer	AEP	May 14/97	7.5	304	718	284	0.09	568	22	<0.05	32.6	1.33	196.2	3400
	Minimum			**6.5**	**36**	**260**	**129**	**0.001**	**0.4**	**0.7**	**0.06**	**10.5**	**0.779**	**117.9**	**560**
	Maximum			**8.2**	**304**	**800**	**284**	**29**	**1485**	**22**	**0.3**	**59**	**1.33**	**470**	**4341**
	Median			**7.55**	**137.5**	**590**	**154**	**0.0465**	**160**	**5.8**	**0.09**	**22.5**	**1.03**	**196.2**	**3400**
	Count			**16**	**14**	**16**	**4**	**16**	**13**	**10**	**3**	**14**	**3**	**5**	**5**

	Site / Location	Analysis	Date	pH	BOD (mg/L)	COD (mg/L)	TOC (mg/L)	Phenol (mg/L)	TSS (mg/L)	O & G (mg/L)	Ammonia - N (mg/L)	Tannin Lignin (mg/L)	Total Phosphorous (mg/L)	Fatty Acids (ug/L)	Resin Acids (ug/L)
1	Aspen	AEP	Jun 19/96	7 29	77	505	126	<0.001	0.4	5.5	0.17	11.4	1.01		
2	Aspen Site	AEP	Sept 6/96	7.68	84	450	165	0.1	28	2	0.06	11.6	0.231	0	10.5
3	Aspen/Conifer	AFPA	Spring/96	7 1	105	500		0.1	1420	2.5		28		487.5	660.7
4	Aspen/Conifer	AFPA	Fall /96	7.6	69	500		0.96		2		28		79	520
5	Aspen/Conifer	AFPA	Fall /96	7.8		450		0.056							
6	Aspen/Conifer	AFPA	Fall /96	7 7		410		0.196							
7	Aspen/Conifer	AEP	Mar 26/97	9 1	1330	3030	945	1.03	960	25	0.11	142	3.01	713	15265
8	Aspen/Conifer	AFPA	Spring/97	7	945	2550		1.3	280	8		178		570	9300
9	Aspen/Conifer	AFPA	Spring/97												
10	Aspen/Conifer	AFPA	Spring/97	6.6	1125	2250		1.6	224	10		165			
11	Aspen/Conifer	AFPA	Spring/97	6.4	840	1800		1.5	56	9 1		130			
12	Aspen/Conifer	AFPA	Summer/97	7.1	291	1190		0.90	475	na		58		79	230
13	Aspen/Conifer	AFPA	Summer/97	7.2	275	1440		1	3015	na		55			
14	Aspen/Conifer	AFPA	Summer/97	7.3	281	910		2.6	110	na		59.2			
15	Aspen/Conifer	AFPA	Summer/97	7.4	534	1200		9.8	24	na		61.6			
	Minimum			**6.4**	**69**	**410**	**126**	**0.056**	**0.4**	**2**	**0.06**	**11.4**	**0.231**	**0**	**10.5**
	Maximum			**9.1**	**1330**	**3030**	**945**	**9.8**	**3015**	**25**	**0.17**	**178**	**3.01**	**713**	**15265**
	Median			**7.295**	**286**	**1050**	**165**	**0.96**	**224**	**6.75**	**0.11**	**58.4**	**1.01**	**283.25**	**590.35**
	Count			**14**	**12**	**14**	**3**	**13**	**11**	**8**	**3**	**12**	**3**	**6**	**6**

Bioassay Results for the Sawmill / OSB Plant - Aspen & Conifer Log Yard - Weyerhaeuser Drayton Valley

Site / Location	Analysis	Date	Trout Bio-assay	Daphnia Magna Bioassay LC50	Daphnia Magna Bioassay EC50	Micro-tox	pH	COD	Phenol	TSS	O & G	Amm - onia	Tannin Lignin	Fatty Acids	Resin Acids
								mg/L	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(ug/L)	
Conifer	AEP	Apr 16/96		> 100 %	> 100 %	58.2%	7.39	260	0.047	145	9.5	0.06	31.7		
Conifer		Jun 19/96		> 100 %	> 100 %	> 100 %	7.93	490	0.018	0.4	5.5	0.09	12.2		
Conifer	AFPA	Spring/96	90%			0.76	7.7	470	0.01	636	3.7		12.7	318.7	960
Conifer	AFPA	Fall /96	> 100%			> 100 %	7.9	500			0.7		10.5		
Conifer		Fall /96					8	430							
Conifer		Fall /96					8.2	420							
Conifer		Mar 26/97		> 100 %		5.9%	7.6	621	0.037	160	11	0.3	19.7		
Conifer	AFPA	Spring/97	32%			60.6%									
		Spring/97				19.3%									
		Spring/97				22.3%									
		Spring/97				25.4%									
Conifer	AFPA	Summer/97	47%			91.2%									
		Summer/97				84.1%									
		Summer/97				> 100 %									
		Summer/97				44.7%									
Minimum			**32%**	**100%**	**100%**	**6%**	**7.4**	**260**	**0.010**	**0.4**	**0.7**	**0.1**	**10.5**	**318.7**	**960.0**
Maximum			**47%**	**100%**	**100%**	**100%**	**8.2**	**621**	**0.047**	**636**	**11.0**	**0.3**	**31.7**	**318.7**	**960.0**
Median			**40%**			**59%**	**7.9**	**470**	**0.028**	**153**	**5.5**	**0.1**	**12.7**		
Count			**3**	**3**	**2**	**13**	**7**	**7**	**4**	**4**	**5**	**3**	**5**	**1**	**1**

Site / Location	Analysis	Date	Trout Bio-assay	Daphnia Magna Bioassay LC50	Daphnia Magna Bioassay EC50	Micro-tox	pH	COD	Phenol	TSS	O & G	Amm - onia	Tannin Lignin	Fatty Acids	Resin Acids
								(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(ug/L)	
Aspen		Jun 19/96		> 100 %	> 100 %	87.6%	7.29	505	<0.001	0.4	5.5	0.17	11.4		
Aspen Site		Sept 6/96		> 100 %	> 100 %	> 100 %	7.68	450	0.1	28	2	0.06	11.6		
Aspen		Spring/96	95%			39%	7.1	500	0.1	1420	2.5		28	487.5	660.7
Aspen		Fall /96													
Aspen		Fall /97													
Aspen		Fall /98													
Culvert 2		Mar 26/97		30%		46%	9 1	3030	1.03	960	25	0.11	142		
Aspen/Con - ifer	AFPA	Spring/97	7.1%			11.50%									
		Spring/97													
		Spring/97				2.37%									
		Spring/97				1.48%									
Aspen/Con - ifer	AFPA	Summer/97	14%			14.7%									
		Summer/97				16.6%									
		Summer/97				20.2%									
		Summer/97				4.86%									
Minimum			**7%**	**30%**	**100%**	**1%**	**7.1**	**450**	**<0.001**	**0.4**	**2**	**0.06**	**11.4**	**487.5**	**660.7**
Maximum			**95%**	**100%**	**100%**	**100%**	**9.1**	**3030**	**1.0**	**1420**	**25**	**0.17**	**142**	**487.5**	**660.7**
Median			**14%**	**100%**	**100%**	**16%**	**7.49**	**502.5**	**0.1**	**494**	**4**	**0.11**	**20**		
Count			**3**	**3**	**2**	**11**	**4**	**4**	**4**	**4**	**4**	**3**	**4**	**1**	**1**